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SNC TECHNOLOGIES CORP..
P.O. Box 576
Avon, CT
USA 06001-0576

Oil Platform Removal Using Engineered Explosive Charges:

In Situ Comparison of Engineered and Bulk Explosive Charges

FINAL REPORT
Background Documents

Prepared by:

Denis Saint-Arnaud (SNC TEC)
Pierre Pelletier (SNC TEC)
William Poe (Explosive Services International)
John Fowler (DRDC Suffield)

Approved by:

Nathalie Maher, Manager, Technologies section

Presented to:

Mr. James Lane
Mineral Management Services, Department of Interior

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Disclaimer

This report has been reviewed by the U.S. Minerals Management Service staff for technical adequacy according to contractual specifications. The opinions, conclusions, and recommendations contained in this report are those of the authors and do not necessarily reflect the views and policies of the U.S. Minerals Management Service. The mention of a trade name or any commercial product in this report does not constitute an endorsement or recommendation for use by the U.S. Minerals Management Service. Finally, this report does not contain any commercially sensitive or proprietary data release restrictions and may be freely copied and widely distributed.

Executive Summary

Part of the mission of the Minerals Management Service (MMS) of the US Department of the Interior (DOI) is to "manage the mineral resources of the Outer Continental Shelf in an environmentally sound and safe manner". This includes the oil platform decommissioning practices in the Gulf of Mexico. While different methods can be used for this task, Explosive Removal of Offshore Structures (EROS) present some cost advantages on shallow water removals. However, a number of alternative removal technologies exist and are used regularly. EROS is also frequently used in deep water where there are significant risks to divers while inspecting the results of removal operations. The current maximum explosive weight authorized by MMS for explosive structure removal is 50 pounds, which is also the upper limit of charge covered by a generic Endangered Species Act (ESA) consultation. A limit value of 5 pounds was determined to be at a "de minimus" level set by another ESA consultation. The blast characteristics of explosive charges and their impact on wildlife have not been completely assessed. Data on current weight limits have been obtained through modeling and extrapolation, hence the MMS expressed a need to obtain data from actual tests, which could later be used to confirm and validate the weight characteristics.

SNC TEC Corporation team was awarded a contract in the fall of 2001 to develop an explosive charge system that would require less explosive to sever offshore structures through the use of an engineered charge and to obtain data to evaluate its impact on marine life. The aim for the engineered explosive charge total system weight was to be below 10 pounds and, if possible, below 5 pounds. The project team was led by SNC TEC. The team was comprised of Explosive Service International (ESI), Defence Research and Development Canada Suffield (DRDC Suffield) and Sonalysts. The team members were involved in different tasks related to charge development and its set-up on the ESI developed Scorpion™ delivery system as well as the different aspects of testing, including blast measurements during final tests in the Gulf of Mexico.

Following simulation studies, a charge system based on linear-shaped charges was developed to severe oil platform piles of 30" and 48" diameters with wall thickness less than 1.5 inches. The Scorpion™ system was used to hold the charges and position them in the piles. Total explosive charge weights of 4.05 and 6.58 pounds were obtained for the 30" and 48" diameter pipes respectively. In the preliminary tests conducted on submerged pipes in a quarry lake, the Scorpion™ system worked well and the charges successfully severed the two different pile diameters of interest. In the tests against actual structures in the Gulf of Mexico, only 30" piles were available for cutting. It is believed that the Scorpion™ system did not deploy properly leading to improper arrangement of the device in the pile resulting in a reduction of the charges effectiveness and incomplete severing. Additional work would be required in order to solve the problem with the system deployment.

The general conclusions of this study are that the values of peak overpressure, impulse and energy flux density obtained from both the engineered and the bulk charges generally follow the accepted exponential shape when presented as a function of the distance from the blast charge divided by the cube root of the charge weight. These values are also closer to those computed with the Connor similitude equation than those obtained with the ARA model which can be expected based on the method used to obtain the equations and the conservative assumptions used to develop the ARA model. The limit values of 12 psi for the peak overpressure and 182 dB (re 1 μPa^2-sec) for the energy flux density are obtained at half the distance for the 4.05 pounds engineered charge than for the 50 pounds bulk charge. Additional experiments should be performed to confirm more precisely the results obtained.

Abstract

The SNC TEC Corporation team conducted a research program related to the Explosive Removal of Offshore Structures (EROS) and its impact on marine life. This work was performed for a contract awarded by Minerals Management Service (MMS) in the fall of 2001. The major goal of the program was to develop an engineered explosive charge system that would contain less explosive than the standard 50-pound bulk charge to undertake the removal of offshore structures. The targeted total weight of the explosive of the new charge was to be below 10 pounds and, if possible, below 5 pounds. Blast measurements to provide data to compare effects on the environment were also taken during the program.

The Scorpion™ system developed by Explosives Systems International (ESI) was chosen as the system to hold the charges and place them inside the pipes to be severed. The development of the engineered charges was based on the advantages of the shaped charge. Numerical modeling and experimental validation were performed on different types of linear-shaped charges. The computer simulation results were used to obtain the optimal dimensions for the linear shaped charge design to be used. These dimensions were found to be close to those of a commercial charge manufactured by Accurate Energetics. A sturdy waterproof casing was designed to hold the complete charge system to ensure adequate functioning and fit on the Scorpion™ . These charges were designed and manufactured for the removal of 30" and 48" diameter piles. Although the design of charges for the removal of 24" piles has been completed, they were not manufactured.

Testing of the design, first at Defence Research and Development Canada (DRDC) Suffield and then at the ESI test range, led to the final development of the charge design containing total explosive charge weights of 4.05 and 6.58 pounds for the 30" and 48" diameter pipes respectively. Tests were then conducted on submerged pipes in a quarry lake to demonstrate the ability of the engineered charges mounted on the Scorpion™ to sever both diameters of pipes and to test the blast measurement array. Good results from all the preliminary tests was followed by validation testing of the system in the Gulf of Mexico against actual structures made of 30" piles. The results showed incomplete severing of the pipes with about two thirds of the pipe circumference uncut. Evidence indicates that an imperfect deployment of the Scorpion™ may be the cause. Additional work will be required to solve the problem with the deployment system.

Measured peak blast overpressure values obtained using the experimentally recorded pressure curves from two 50 pounds bulk charge and the engineered charge were studied along with the impulse and the energy flux density computed from those pressure curves. This data was reviewed as a function of the distance from the charge divided by the cube root of the charge weight. While general tendency of the data for both types of charge was to follow the generally accepted exponential shape of similitude equations, this data was relatively scattered, as indicated by regression coefficients (R^2) between 0.40 and 0.90. The measured data did not also always follow the expected pressure reduction with the distance from the blast point. For both types of charges, the measured data is closer to the computed data from Connor study similitude equations compared to the Advanced Research Associates (ARA) model particularly for impulse and energy flux density. This can be expected since the ARA model was developed from theoretical conservative assumptions while the Connor similitude equations were derived from experimental data. The peak overpressure data of the engineered charge were generally lower than the bulk charge data. The computed distance to obtain the 12 psi peak blast overpressure and 182 dB (re 1 μPa^2-sec) energy flux density with the engineered charge is about half that obtained with the bulk charge. This corresponds closely to the ratio of 2.31 for the cube root of the bulk charge weight and engineering charge weight.

Preface

The background documents presented here are a collection of technical data, drawings, reports and minute meeting which have been emitted in the realization of the contract related to the explosive removals of offshore structures (EROS) and its impact on marine life since the fall of 2001 to the winter of 2003-2004. most of these documents were already transmitted to Minerals Management Service (MMS) along with the monthly reports.

These background documents are complementary to the final report. They are not essential to the reading of the main report but could help to make some details more clear in furnishing some basic details.

LIST OF ABBREVIATIONS

ALE	Arbitrary Lagrangian Eulerian
ARA	Advanced Research Associates
CD	Charge width for linear shaped charge and charge diameter for axisymetric shaped charge
Composition B	Explosive formulation made 06 59.5% RDX, 39.5% TNT and 1% wax
Composition C4	Explosive formulation made of 91% RDX in 9% polyisobutylene binder
CTD	Conductivity, temperature and depth
DRDC-S or DRDC Suffield	Defence Research and Development Canada - Suffield
EROS	Explosive Removal of Offshore Structures
ESI	Explosive Systems International
GOM	Gulf of Mexico
HSS	Hollow Structural Section
LSTC	Livermore Software Technology Corporation
LSC	Linear Shaped Charge
MMS	Mineral Management Services
nonel	non-electric
PETN	Pentaerythritol tetranitramine explosive
PVC	Polyvinyl chloride
RDX	cyclotrimethylenetrinitramine or cyclonite explosive (abbreviation stands for Research Department Explosive)
SNC TEC	SNC Technologies Inc.
SNC TEC Corp.	SNC TEC Corporation; American branch of SNC TEC

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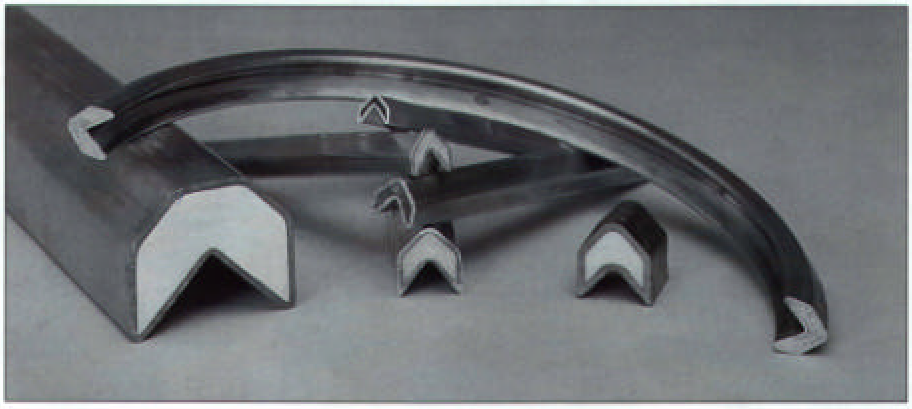
Annex A

Accurate Energetics linear shaped charge data

The Accurate Companies

TECHNICAL DATA

LINEAR SHAPED CHARGE



Description

Accurate's Linear Shaped Charge (LSC) is an explosive enclosed in a seamless metal sheath and fabricated in continuous lengths shaped in the form of an inverted "V."

When detonated, the V-shaped metal liner with explosive core produces a uniform linear cutting action. This cutting action, known as the "Monroe effect," can be accentuated by controlling LSC dimensions and configuration, explosive type and load, liner thickness, and continuity.

At detonation, the focusing of the explosive high pressure wave as it becomes incident to the side wall causes the metal liner of the LSC to collapse—creating the cutting force. If the standoff distance is optimum, collapse of the liner will be complete before it reaches the target as a plasma jet. This high velocity jet impacts the target with pressures exceeding the target's yield strength and literally pushes the target material to either side of the path of the jet.

The liner may be formed using any malleable metal, but is typically copper, aluminum, lead or silver. Copper is generally used with most large core loads, but for some applications, Aluminum is recommended to provide structural integrity. For small core loads where flexibility is required, Lead is preferred, while Silver is reserved primarily for use with thermally-resistant explosive core loads.

The explosive core loads commonly used in Accurate's LSC are RDX, HMX, PETN, HNS and PYX. The detonation rates for each are as follows:

RDX: 8,200 meters/second @ 1.65 g/cc.
HMX: 9,100 meters/second @ 1.84 g/cc.
PETN: 8,300 meters/second @ 1.7 g/cc.
HNS: 6,900 meters/second @ 1.6 g/cc.
PYX: 7,200 meters/second @ 1.68 g/cc.

Performance

The cutting ability of LSC is affected by a number of variables, including the detonation rate of the explosive core load, the characteristics of the metal liners, and the density of the material being cut.

There is, however, a general scaling guide which may be used to determine the penetration as related to core load, in that penetration of a given material is essentially proportional to the square root of the core load. The formula is as follows:

$$T_1 = T_2 \sqrt{\frac{W_1}{W_2}}$$

T_1 = unknown penetration depth
T_2 = recorded penetration by W_2 core load
W_1 = select core load
W_2 = recorded core load

Please recognize that all analytical comparisons and reported data were obtained under controlled test conditions and should be considered as relative only.

The Accurate Companies

CHARACTERISTICS

LINEAR SHAPED CHARGE

Copper LSC

*Core Load Grains/Foot**	*Width*** *(In.)*	*Height*** *(In.)*	*Approx. Gross Weight (Lbs./Ft.)*	*Approx. Standoff (In.)*	*Penetration† at Optimum Standoff (In.)*
100	.28	.25	.07	.20	.25
150	.35	.31	.20	.20	.30
250	.45	.38	.22	.35	.40
400	.48	.53	.31	.37	.55
600	.68	.58	.51	.60	.70
900	.76	.68	.70	.66	.85
1,200	.89	.92	.96	.75	1.00
2,000	1.15	1.04	1.31	.75	1.50
3,200	1.43	1.23	1.66	1.00	1.70
4,400	1.81	1.41	2.50	1.25	2.25
10,500	2.56	1.78	4.30	2.00	3.50

Cast LSC

In addition to formed Linear Shaped Charge, Accurate offers a Cast LSC in various lengths and explosive weights. Length and configuration can be manufactured to meet most needs. Popular applications for cast charges include oil well control situations and for cutting heavy-walled steel structures. Cast LSC can be manufactured with either steel or aluminum housings, and can be poured with a variety of explosives to include Octol, Composition B and Hexolite.

Aluminum LSC with core loads of 22-600 grains/foot are available on request.
**Explosive Core Loading tolerance is ±10%.*
***Dimensional tolerance is ± .020.*
†Performance shown is for RDX explosive into 1018 mild steel.

Y 0 0 0 – 0

- Grain Load Per Foot
- Core Material: 0-RDX, 1-PETN, 2-CH-6, 3-HNS, 4-HMX, 5-PYX
- Sheath Material: 0-Lead, 1-Silver, 2-Aluminum, 3-Copper, 4-Pewter
- Product Type: 2-Linear Shaped Charge (LSC)

Example: Y230-200 is a Linear Shaped Charge with a copper sheath and 200 grains/foot of RDX core.

The Accurate Companies

5891 Hwy. 230 West, McEwen, TN 37101 • (931) 729-4207• (800) 416-3006 • fax (931) 729-4211

Annex B

DRDC Suffield testing report (Task 4)

OIL PLATFORM REMOVAL USING ENGINEERED CHARGES
TASK 4: EXPERIMENTAL FIRINGS AT DRDC-SUFFIELD
SUMMARY REPORT

John Fowler
16 March 2003

Introduction

Testing of selected linear and curved commercial shaped charges against pile material occurred as planned at DRDC-Suffield March 3-6, 2003. The following report summarizes these experimental trials and the results. A summary of the trial series is given in Table 1, 2 and 3 provided below. The initial test plan for this week and a summary in table form of the planned trials is provided as Appendix A. While testing was ongoing Martek Inc performed a series of simulations to demonstrate the water jetting phenomena which results from an annular detonation bubble collapse, some of this work is provided as Appendix B.

Over the course of testing shaped charge liners packed with RDX and Comp-B were evaluated against water-backed 1.5" thick steel to determine their performance. Linear charges were tested both in air and inside steel casings designed to be sealed and allow the charges to be submerged. Problems with the initiation system were encountered and several small tests were performed to support the trial series. Having successfully initiated a linear charge in a casing a curved version was tested and three of these charges were then fired against a 48 inch diameter section of 1.5 inch thick pile material. Time constraints pushed an identical trial using Comp-B charges into the following week.

Table 1: Trial Summary - Initial testing of linear charges with no casings.

Test #	Trial Date	Explosive	Charge	Casing	Standoff	Target	Details
1	3 Mar 03	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water-backing of steel plate to obtain proper spall behaviour.
2	3 Mar 03	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water saturated sand backing.

Table 2: Trial Summary - Testing of initiation concepts through steel casing.

Test #	Trial Date	Acceptor Explosive	Donor Explosive	Casing	Witness	Detonation	Details
3	3 Mar 03	5/8" Disk	¾" C4 well 3/8" Deep	1/16"	1/16"	No	
4	3 Mar 03	5/8" Disk	C4 well + 5/8" Disk	1/16"	1/16"	Yes	
5	3 Mar 03	N/A	C4 well + 5/8" Disk	1/16"	N/A	Yes	
6	4 Mar 03	5/8" Disk	C4 well + 5/8" Disk	1/16"	1/16"	No	Detonator side mounted.
7	4 Mar 03	5/8" Disk	Detaprime + 5/8" Disk	1/16"	1/16"	Yes	Detonator side mounted. Detaprime (5g)

(5/8" Disk refers to a 5/8" disk of 1/8" thick Detasheet.)

Table 3: Trial Summary-Evaluation of commercial shaped charges

Test #	Trial Date	Explosive	Charge	Casing	Standoff	Target	Details
8	4 Mar 03	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water-backing of steel plate.
9	4 Mar 03	RDX	Straight 12 inch	Straight 12 inch	1.25 inch	Steel Plate 1.5 inch	Charge sealed within the submerged casing.
10	4 Mar 03	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water-backed plate with dual initiation on charge.
11	5 Mar 03	RDX	Straight 12 inch	Straight 12 inch	1.25 inch	Steel Plate 1.5 inch	Charge sealed within the submerged casing.
12	5 Mar 03	RDX	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Air-backed plate with charge in casing to confirm initiation.
13	6 Mar 03	RDX	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Three charges sealed inside cases and submerged.
14	6 Mar 03	Comp B	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Air-backed plate with charge in casing to confirm initiation.
15	13 Mar 03	CompB	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Three charges sealed inside cases and submerged.

Experimental Setup and Results

The trials have been summarized below in the order they were performed. The details of the charge preparation, trial set-up and results for each of the trials is provided.

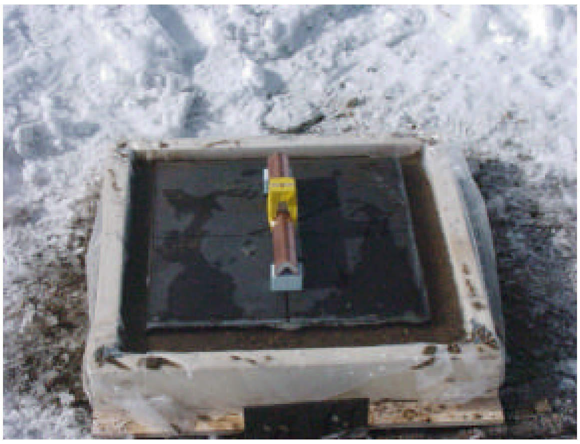
Trial 1

A twelve-inch linear charge was fired against a water-backed one and a half inch mild steel plate. The primadet zero delay MS detonator was mounted vertically. The detonator was used to initiate a ¾” diameter well of C4 explosive 3/8” deep that was in contact with the shaped charge case.

This trial resulted in the partial penetration of the target plate. The point initiation of the shaped charge resulted in a lower penetration below the detonator.

Trial 2

A twelve-inch linear charge was fired against a water saturated sand backed one and a half inch mild steel plate using an identical initiation system to that of the first trial.



As seen in the first trial penetration of the plate did not occur under the detonator. The width of penetration is greater than it appears in the photo due to problems in sectioning the plate. The true performance is similar to that noted in the first trial.

This lower penetration under the detonator has been noted in previous testing with single point initiation systems.

Trial 3

Testing prior to this trial series indicated that there may be problems with initiating the shaped charge through the sealed steel casing. Tests were performed using 1/8" and 1/16" steel plates with a donor charge above the plate and an acceptor charge below the plate. This was then placed in contact with a steel witness plate. In the event of a detonation a hole the size of the acceptor charge would be created in the witness plate. If the system failed to detonate the plate would simply bend as a result of the blast from the detonator and the donor system.

Initially the detonator was placed in a well of C4 (3/8" deep and 5/8" in diameter). A layer of C4, 1/8" thick, located by a particle board form could not be detonated below a 1/8" or 1/16" plate. This trial was then repeated with a 5 gram detaprime around the detonator and a 3/8" disk of C4 1/8" thick as the donor charge. The system again failed to detonate the C4 below the 1/16" plate representing the charge casing.

For trial 3 the primadet detonator was placed in a ¾" diameter well of C4 3/8" deep. This donor charge was place on top of a 1/16" steel sheet with a 5/8" disk of 1/8" detasheet below. The detasheet disk was secured in place using a piece of particle board with a hole sized to the disk. This acceptor system was then placed on a steel witness plate.

The witness plate indicated that the acceptor charge did not detonate.

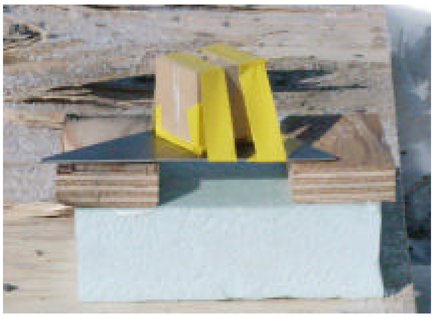
Trial 4

The previous trial was repeated with a 5/8" diameter disk of 1/8" detasheet below the C4 well as the donor charge. The acceptor charge was identical to the previous trial.

This resulted in detonation of the acceptor charge.

Trial 5

Concerns were raised with respect to the donor charge, was the charge detonating or transitioning to detonation. A trial was conducted with just the donor system and a witness plate.



While the metal disk punched out of the witness plate was not recovered, the damage seen on the witness plate and the hole in the plywood shown to the right of the plate indicated that it had been formed.

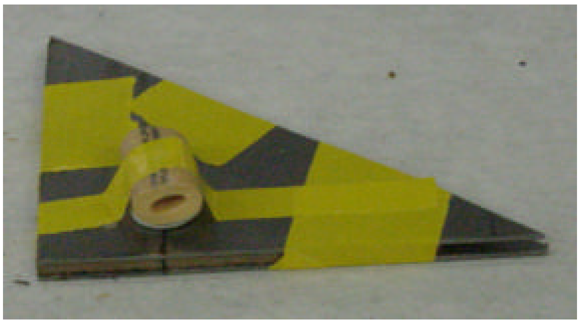
Trial 6

The steel tube casing designed by SNC was made such that the detonator would be mounted horizontally along the top of the case. This initiation concept was tested to ensure the detonation would propagate through the case. The detonator was placed in a well of C4 and positioned on top of a 5/8" diameter disk of 1/8" detasheet.

The results indicated that the detasheet acceptor charge below a 1/16" plate was not initiated.

Trial 7

The side initiation concept was repeated with a five gram detaprime on top of a 5/8” disk of 1/8” detasheet. This donor charge was placed on top of a 1/16” steel plate with a similar detasheet disk below, located by the particle board as shown in the figure below. This was then placed on a 1/16” steel witness plate to determine if the acceptor charge had detonated.

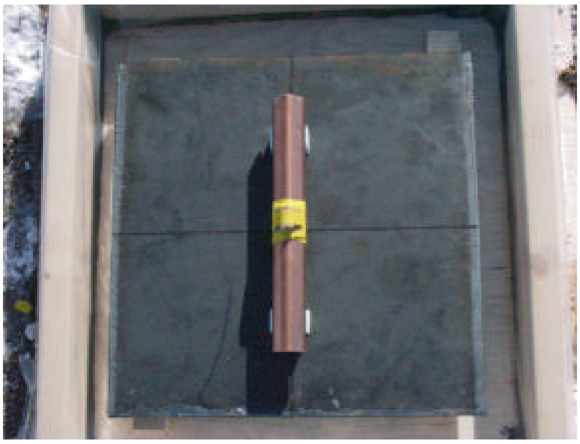


The figure below indicates that the acceptor charge did in fact detonate.

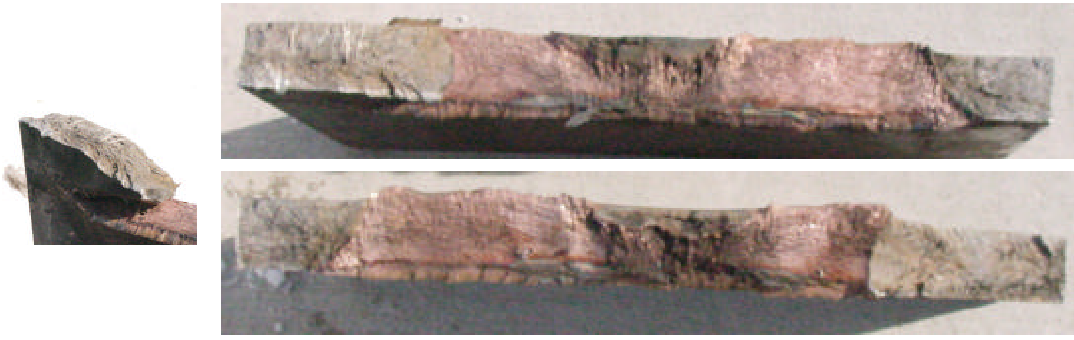
The steel plate at the bottom right was that used to model the steel casing, above it is the steel witness plate. To the right is the plywood base with a hole created by the recovered steel disk shown.

Trial 8

Based on the results of trial one and two, options for increasing the cutting performance under the initiation point were discussed. The concept of adding a 1.5 inch by two inch layer of 1/8" detasheet below the 5 gram detaprime was considered and tested.



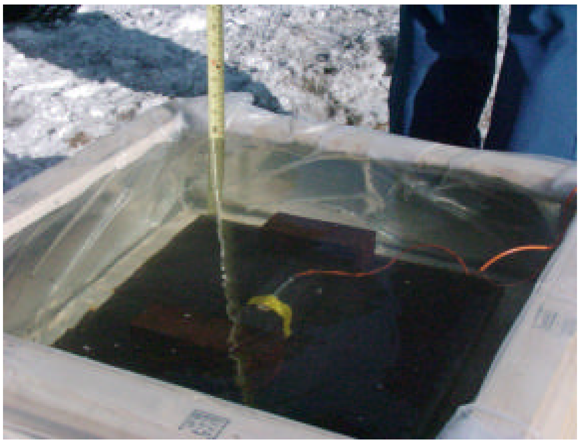
The results are provided below.



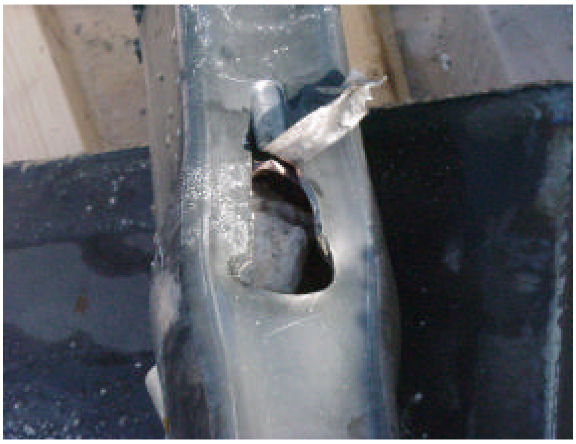
While the additional explosive was sufficient to result in the plate fracturing the depth of penetration was not significantly different from that of the first trial.

Trial 9

A twelve inch linear RDX charge was then sealed inside a steel casing. The acceptor charge consisted of a 5/8” disk of 1/8” detasheet with C4 packed below it to make contact with the shaped charge. The donor charge used a primadet detonator with a five gram detaprime on top of a 5/8” disk of 1/8” detasheet in contact with the sealed steel casing.

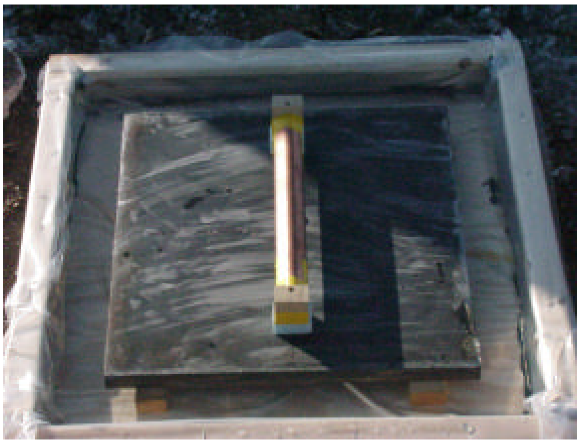


The acceptor charge failed to detonate resulting in the shaped charge also not detonating.

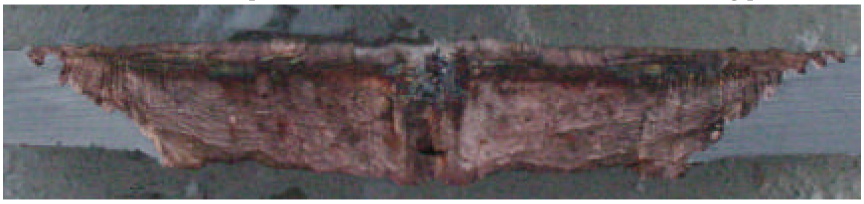


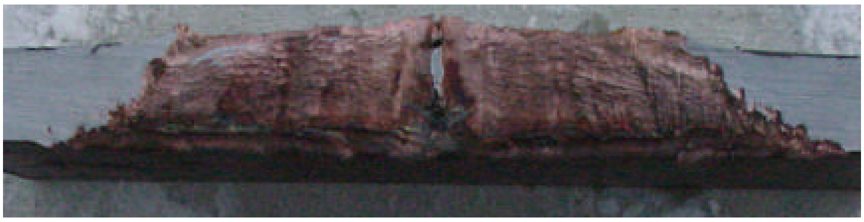
Trial 10

Questions have been raised during the course of this work regarding the benefit of multiple initiation. To determine the benefit afforded by colliding detonation and blast waves on the performance of a linear shaped charge a dual initiated system was tested. Two RP-83 detonators were used for timing purposes. These detonators initiated a 5/8" disk of 1/8" detasheet placed on either end of the shaped charge.



The plate was water-backed to limit the spall and obtain a better estimation of the cutting potential.

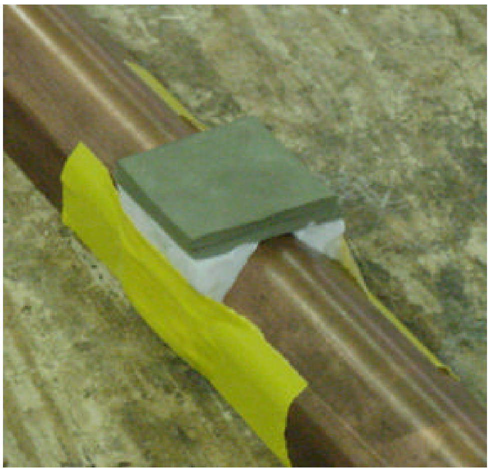




As expected from previous testing the shock collision effect is localized at the center of the cut. While there is a continuous penetration the total length of the cut is significantly shorter than the other trials done here due to the run up required on either end of the charge.

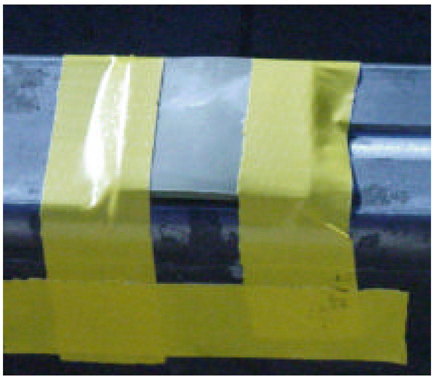
Trial 11

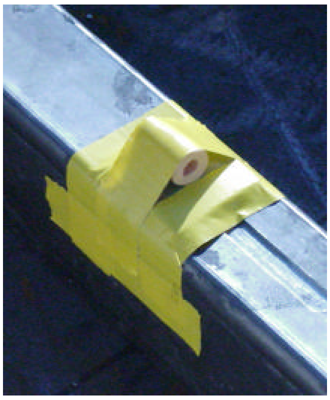
Based on the previous trials a substantial initiation system was developed to ensure detonation of the shaped charge. Two 1.5 inch by 2 inch layers of 1/8" detasheet were placed on top of two wedges of C4 that made contact with the RDX linear shaped charge.



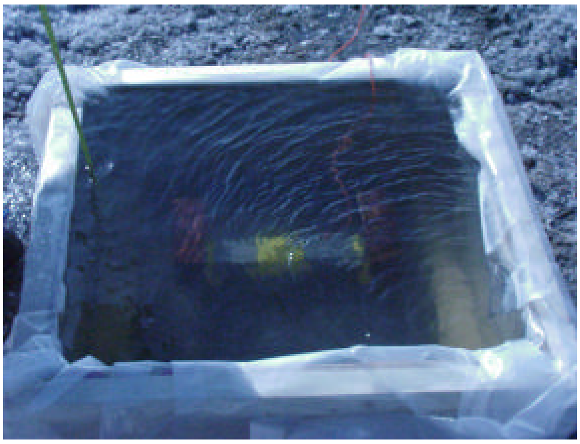
This acceptor charge was secured with tape and placed within the steel casing. The shaped charge and initiation system were pushed into the top of the steel casing using a spring system.

The casing was then sealed with gasket material. The booster charge on top of the steel casing consisted of two 1.5 inch by 2 inch layers of 1/8" Detasheet taped to the case and a 5 gram detaprime.



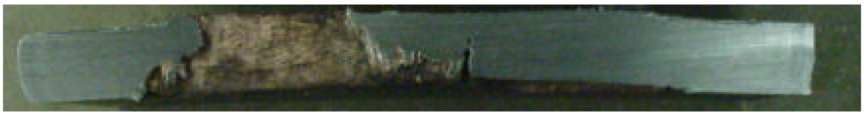


The charge was then placed on the 1.5 inch target plate and submerged for the trial.



This system did initiate the charge but poorly. The cut suggests that detonation occurred on only one side of the system. This resulted in no jet being formed below the initiation system.

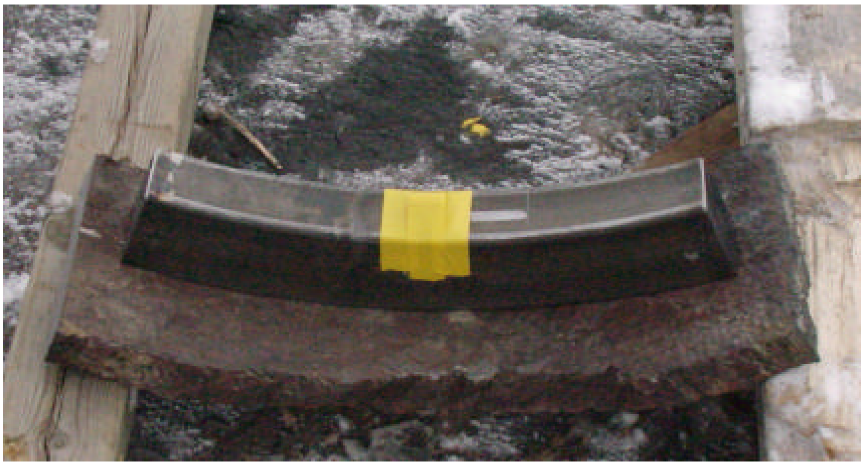
The detonation wave does run-up and balance itself quickly and the plate was penetrated away from the initiation system.



While not on the same plane a cut of similar dimensions occurs on both sides of the initiation system.

Trial 12

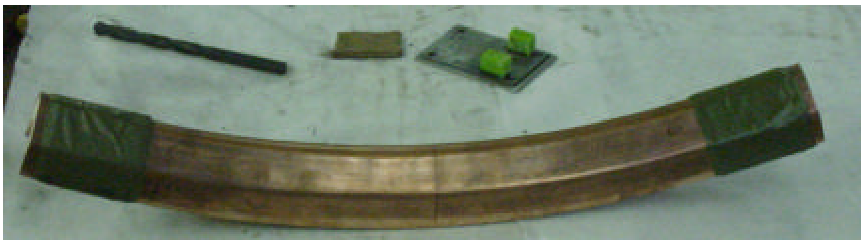
Having initiated the linear charge the same system was built and tested for a curved RDX shaped charge. During preparation of the charge extra care was taken to ensure a tight fit between the charge and the casing.



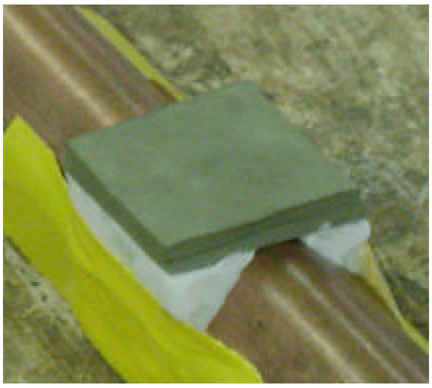
The trial was performed on an air-backed section of pile material. The system successfully detonated the shaped charge and cut the plate.

Trial 13

Having successfully initiated the curved charge three of these systems were built to fired against the 48 inch diameter section of pile material. The charges were first wrapped with tap to ensure a tight fit in the charge casing.

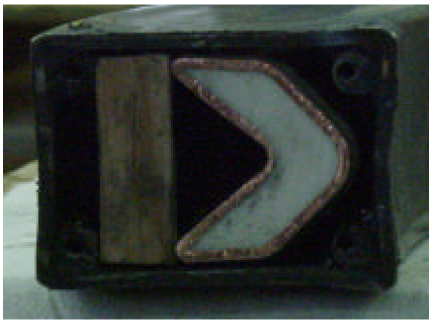


The acceptor charge of C4 and data sheet was then added at the center of the charge.



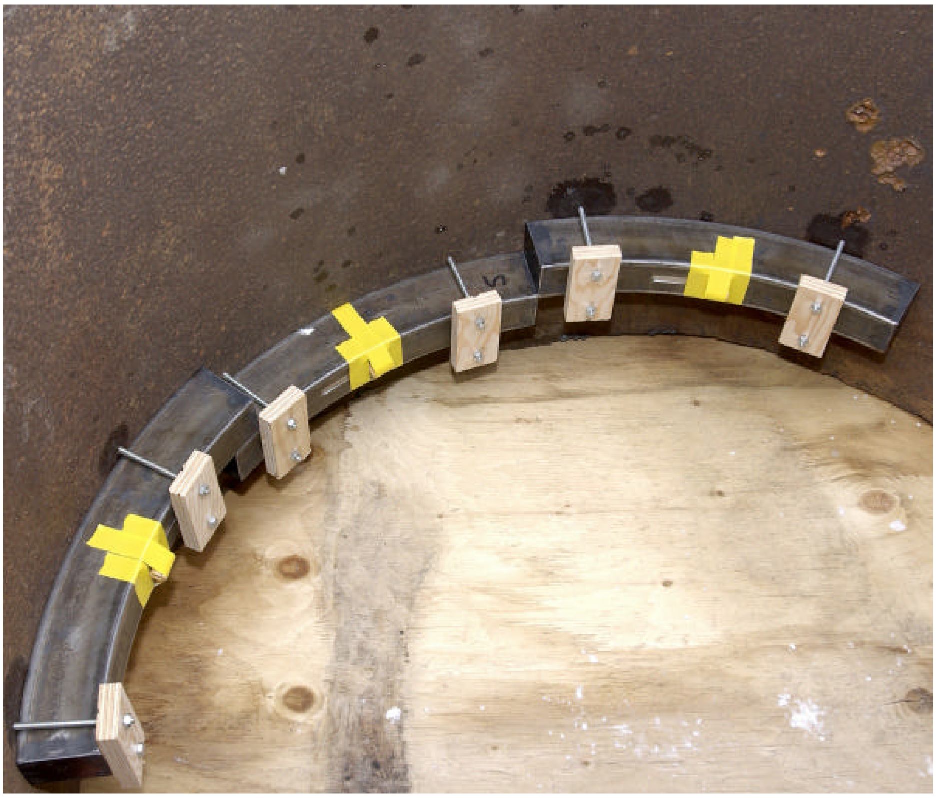
The charge was then slid into the curved steel casing.

The endcaps are shown in this figure. The cap with the protane blocks was installed first with the base of the charge resting on the blocks to establish the proper standoff. The wooden block was then used to wedge the charge in place and ensure good contact of the acceptor charge with the top of the steel casing.



Having dry fit the components the gasket material was then added to the endcaps and they were screwed securely into place sealing the internal cavity. Four curved Comp-B charges were also completed at this time in the same manner.

The three RDX charges were placed inside the pile. The ends of the charges were positioned such that at one interface there was a 1.5 inch overlap while at the other the charged were flush with each other and offset by the width of the charge casing.



The pile was positioned in a 6.5 foot diameter steel tube that was lined with polyethylene sheet. The inside and outside of the pile were then filled with water. There was 24 inches of head on the mid-plane of the charges for the trial. This results are shown below;

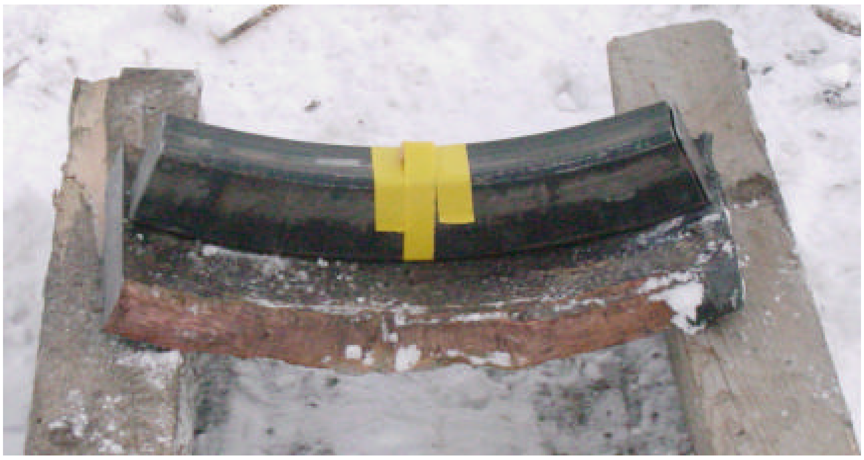
All three charges successfully detonated. The charges that were flush and offset by the charge case width resulted in a significant brittle fracture of the pile at the interface. It was noted that most of the pile shots using the SCORPION™ system showed a similar characteristic fracture pattern. The outside charge in this case did not fracture through to perforate the pile under the detonator. This may have been a result of interaction with the crack running to the bottom of the pile. This could also result from interaction of the charges if they were initiated at slightly different times.

The crack had propagated between the two offset cuts joining the cutting planes.

The overlapped charges did perforate the plate and a crack propagated between the two cutting planes. The outer charge appeared to stop cutting prior to the end of the charge as this cut appears shorter than the shaped charge. This will be confirmed when the plate is sectioned.

Trial 14

A Comp-B curved charge in a case with an identical initiation system was fired in air to confirm the initiation system was adequate.



The charge initiated and split the section of pile material. The brittle fracture that severed the plate had copper on the fracture surface suggesting that the charge was still cutting when it was disrupted by the fracture.

Trial 15

Trial 13 was repeated using Composition-B rather than RDX filled charges. The charges had approximately 25 inches of head for the shot.

All of the charges successfully initiated but they only partially penetrated the pile wall. The penetration was lower than that of the RDX charges and there was no cracking between the cutting planes.

Perforation did not occur under the initiation systems.

In the figure above the left and the central charges are shown perforating the pile away from the detonator. The charge on the right perforated a smaller length than the other two charges.

Conclusions

The following conclusions are drawn from this trial series;

Shaped charge penetration is not significantly affected when saturated sand is used rather than water to back the target.

Penetration is reduced below the initiation system.

A detasheet based initiation system proved the most successful. The importance of ensuring contact of the acceptor and donor system with the case was evident from the testing.

Dual initiation increases the penetration in a localized area where the detonation waves interact. This increase comes with the cost of reduced overall penetration as the charge runs-up from two points.

Cracking of the pile as a result of shock or blast interaction improved overall performance for the RDX charges. This characteristic fracture pattern has been noted on many previous shots by ESI.

The RDX charges outperformed the Comp-B charges, perforating the pile and resulting in additional blast related damage.

APPENDIX A

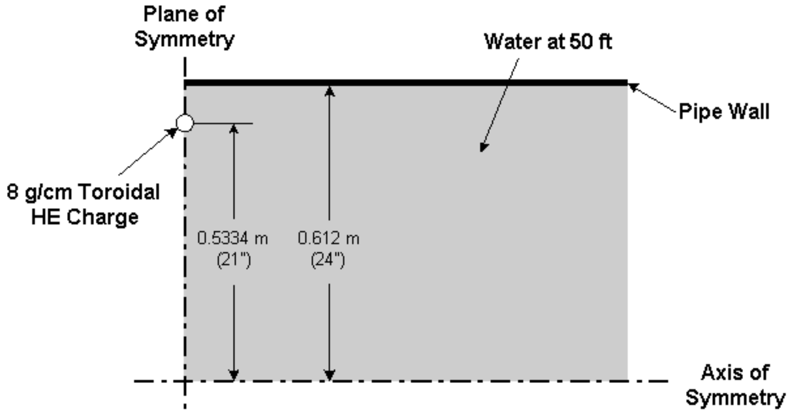
Initial Trial Plan

Test #	Explosive	Charge	Casing	Standoff	Target	Details
1	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water-backing to obtain proper spall behaviour.
2	RDX	Straight 12 inch	None	1.25 inch	Steel Plate 1.5 inch	Water-backing to obtain proper spall behaviour.
3	RDX	Straight 12 inch	Straight 12 inch	1.25 inch	Steel Plate 1.5 inch	Charge sealed within the submerged casing.
4	RDX	Straight 12 inch	Straight 12 inch	1.25 inch	Steel Plate 1.5 inch	Charge sealed within the submerged casing.
5	RDX	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Three charges sealed inside cases and submerged.
6	CompB	Curved 14 inch	Curved 14 inch	1.25 inch	48” Pile 1.5” Thick	Three charges sealed inside cases and submerged.

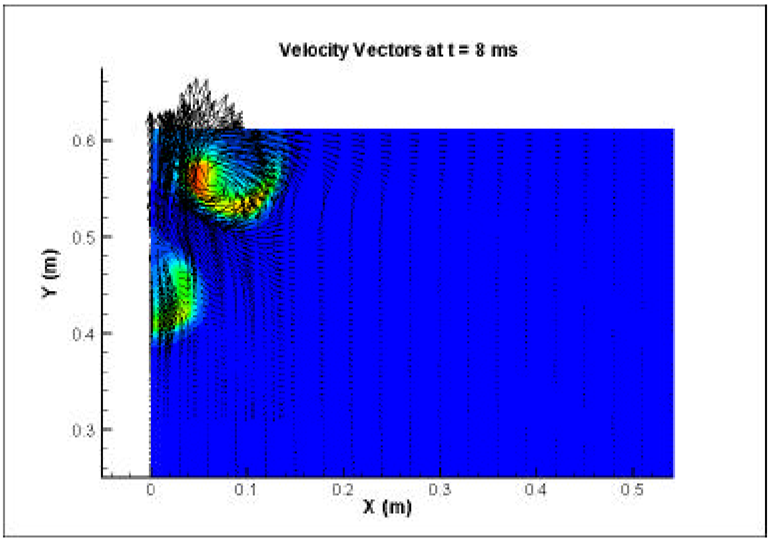
<Attach SNC MMS Trial Series Test Plan >

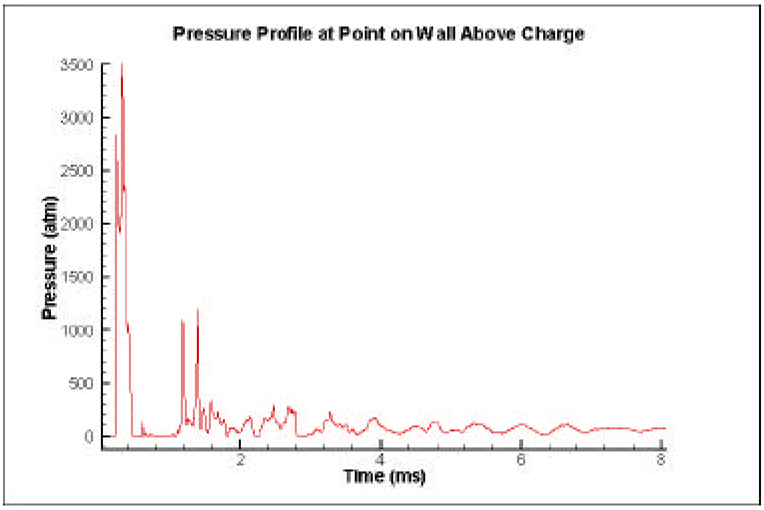
APPENDIX B {SUBJECT TO APPROVAL BY MARTEC}

MARTEC – UNDEX Bubble Collapse for Ring Cutting Charge
www.martec.com
Combustion Dynamics Group
Dave Whitehouse and Laura Martin
28 February 2003



Toroidal bubble forms
Bubble splits during collapse
Low-speed jet (~20 m/s) evident
Bubble jet does not appear to apply high pressure loads to pipe wall
Overall internal pipe pressure high - helps maintain solution stability




Pressure Profile at Point on Wall Above Charge
Pressure (atm)
3500
3000
2500
2000
1500
1000
500
0
2
4
6
8
Time (ms)

Annex C

March 24th, 2003 Minutes of meeting

SNC TEC

COMPTE RENDU DE RÉUNION / *MEETING REPORT*

TITRE DU PROJET / *PROJECT TITLE:*	Oil Platform Removal Using Engineered Explosive Charges		
OBJET / *SUBJECT* **:**	Program Review Meeting		
Date :	24-03-2003	**No. du projet /** *Project No* **:**	647-355
Endroit / *Location* **:**	Videoconference SNC TEC-Québec/MMS-Herndon & MMS-New Orleans	**No. contrat /** *Contract No.* **:**	1435-0101-CT-31136

PARTICIPANTS (Nom & Compagnie) / *ATTENDEES (Name & Company)* **:**			
Jim Lane MMS	Sharon Buffington MMS	Michael Hargrove MMS	Arvind Shah MMS
Tommy Broussard MMS	William Poe ESI	John Fowler DRDC Suffield	Pierre Pelletier SNC TEC
Denis Saint Arnaud SNC TEC			
ABSENTS (Nom & Compagnie) / *ABSENTEES (Name & Company)***:**			
Sarah Tsoflias MMS	Judy Wilson MMS		

ITEM	DISCUSSION	ACTION
1.	Approval of proposed agenda and participants introduction - The proposed agenda was accepted; it is presented in Annex A. - The participants introduced themselves.	
2.	General overview of the project Pierre Pelletier presented the goal and the differents tasks of the project. His presentation can be found in Annex B. -Some questions and remarks were raised from overview of the project but it was agreed to discuss them later. An important point was raised according to the contract. The title given to the option 'Design improvement' which is in reality Task 5 and is already covered in main contract. The option refers to blast measurements to perform during task 7. This is agreed by everybody and unless required by MMS, it will mot be changed.	

3.	Review of work done John Fowler presented the test plan for the tests done at DRDC-Suffield in task 4 and the results obtained His presentation can be found in Annex C His conclusions were: •Shaped charge penetration is not significantly changed if saturated sand with water is used or water is used to back the target. •Penetration is reduced below the initiation system. •A detasheet based initiation system proved the most successful. The importance of ensuring contact of the acceptor and donor system with the case was evident from testing. •Dual initiation increases the penetration in a localized area where the detonation waves interact. This increase comes with the cost of reduced overall penetration as the charge runs-up from two points. •The RDX charges outperformed the Comp-B charges, perforating the pile and resulting in additional blast related damage. Some Questions and remarks were raised from review of work done; The tests at DRDC Suffield having been done with water and sand as backing material, it was asked if clay would have done a difference? Based on his experience John Fowler indicated that he would expect that no significant difference should be noted with clay as the backing. It was asked if the RDX having superior penetration than comp B was a surprise, but it was answered that this is in accordance with the physical output of both explosives. Comp B is made of 60% RDX and 40% TNT. TNT is less powerfull than RDX. The question of overlapping the extremities of the charges was discussed and no clear benefit could be concluded on overlapping from the test conducted. Subsequent discussion and comments by participants led to the conclusion that overlapping could reduce the risk of forming a tab. Another question was, does the lateral cracks created at the point of meeting of two charges could have a detrimental effect on the removing of the cutted piles. It was concluded based on the knowledge of the people present that it shouldn't have any effect. In fact, Mr Poe already met this kind of situation and this did not affect his operation.	

4.	Design Review Pierre Pelletier & Denis Saint Arnaud presented the design review. Details of this presentation can be found in Annex B Some Questions and remarks were raised from design review; When the charge weight was presented Mr. Poe indicated that there is talk of removing the five (5) pounds limit for not using the 'turtle watch'. This subject will be discussed in more details later. Watertightness of the casing was discussed. Even if preliminary tests showed the casings using the gasket sealing compounds watertight at 15 foot depth, further tests is planned at more realistic depth ˜ 200 foot depth. Modification of the Scorpion was discussed. The Scorpion design was made simpler with four moving parts and charge in the deployment system. This scorpion design is usable with the actual casing-charge system. The modifications to the Scorpion design are not actually protected (intellectual property) which is why drawing are not included in this presentation.	
5.	Future work Pierre Pelletier & Denis Saint Arnaud presented the future work. Details of this presentation can be found in Annex B Some Questions and remarks were raised on this subject: On Task 5, Mr Poe is looking to perform differents tests at some water depth or representing differents water depth to complete assurance of watertightness of the casings. Questions on the wall thickness and diameter of the piles to address were raised. For the work so far 48 inches diameter pile with 1½ inch thick wall was selected. The 48" ø, 1½" wall thickness piles being consider a large diameter with a thick wall pile, was the reason for this choice. If change of pile diameter has to be addressed, they should be smaller with thinner wall, which should insure sufficient performance of the charges. In addition to this discussion it has been stated that if different target than 48" pile ø has to be addressed in task 5 or 7 it should be known as soon as possible to perform related design work required and fabricate new tooling if required. The initiation tests to be performed at ESI will be done with already fabricated 45° charges and casings. Other tests will be performed with 90° charges to be made as part of Task 6. For Task 6 the planned work was presented in annex B and agreed by everybody. The size of pile to address which is directly related to the charges fabrication will be discussed in Task 7.	

5.	For Task 7 it has been discussed that this include some preliminary tests at ESI. -Piles to section Size of pile to section was discussed along with the effort require to cut different sizes and it was concluded that we should focus on 48" piles job. However if required we may have to go down to 36" pile diameter. It is agreed that if casing and charges are produced to meet the actual requirements, the cost of manufacture two types of differents charges will have to be considered. Some decommissioning program program were mentionned, Mr Poe and Mr Shah will have a look at them to selection the most appropriate one. -Permits The five pounds limit might be removed. However it appears that the turtle watch could be carried by MMS people present on board. Mr Broussard will do verification on this point. -Sonalysts option The proposition from Sonalysts along with the MMS preliminary requirements is in Annex B. Specific disposition of sensors as per MMS requirements hasn't been established. It was mentioned that no sensor below mud line was planned. Discussion took place regarding preliminary tests before going offshore. Two locations were indicated as possible places where theses tests could be held. It was concluded interesting to perform these tests and that they would be performed depending on the cost. Sonalyst will be contacted regarding the cost of additional testing and the time availability. In addition it is proposed that Sonalyst representatives should be present in a meeting with people from MMS and NMFS to discuss the proposed method. The aim being to check if they agree with the proposed method and insure that the data and measurement are what they are looking after. Insure that these data and their measure is in accordance with what they require. A formal budget proposal would be required.	Action 1 Action 2 Action 3
6.	Schedule presentation Everyboby agree that the revised 'Project Schedule' is a very aggressive schedule which relys on perfect sequence of events. The testing offshore will have to be given a longer period of time. A modified schedule will be send by SNC TEC.	Action 4
7.	Adjourn	
.		

EFFECTUÉ PAR / *PREPARED BY* **:**	**DATE**

LISTE DE DISTRIBUTION / *DISTRIBUTION LIST***:**

ATTENDEES:

SARAH TSOFLIAS MMS

CHARLES E. SMITH MMS

JUDY WILSON MMS

MARJORIE FRANCOEUR CCC

JEAN-MARC PIGEON SNC TEC

NATHALIE MAHER SNC TEC

Actio n	**Date Émise/** *Effective Date*	Description	Responsable / ***Responsible***	Statut / ***Done***	**Date visée/** *Requested for*
1	2003/03/24	Decommissioning program verification (piles ø and thickness)	Mr Poe & Shah		2003/03/31
2	2003/03/24	Verification of acceptance of Turtle watch by MMS people	Mr Broussard		2003/04/14
3	2003/03/24	***Budget proposal for Sonalysts additional tests & meetings***	Saint Arnaud		2003/04/21
4	2003/03/24	Modified schedule	Mr Pelletier		2003/04/21

ANNEXES

Annex A
Meeting agenda

MONDAY, MARCH,24h, 2003 Video conference SNC TEC(Montreal), MMS(Herndon and New Orleans)			
TIME*	ITEM	ACTION	SUPPORT
09:00	Beginning of meeting		
09:15	General overview of the project – Goals – General work plan	 P. Pelletier P. Pelletier	 D. St-Arnaud D. St-Arnaud
09:35	Review of work done – Experimental testing at DRDC-Suffield – Discussion of results	 J. Fowler All	D. St-Arnaud
10:35	Design review – Initiation system – Charge weight and design – Casing design – Modification of Scorpion	 P. Pelletier P. Pelletier D. St-Arnaud W. Poe	 W. Poe W. Poe W. Poe J. Fowler
11:00	Future work (presentation and discussion) – Design improvement (Task 5) – Manufacturing of charges (Task 6) – Full scale tests in Louisiana (Task 7) o Piles to section o Permits o Sonalysts option	 P. Pelletier D. St-Arnaud A. Shah W. Poe D. St-Arnaud	 W. Poe P. Pelletier W. Poe All
11:45	Review schedule and discussions	P. Pelletier	All
12:00	Adjourn		

Annex B

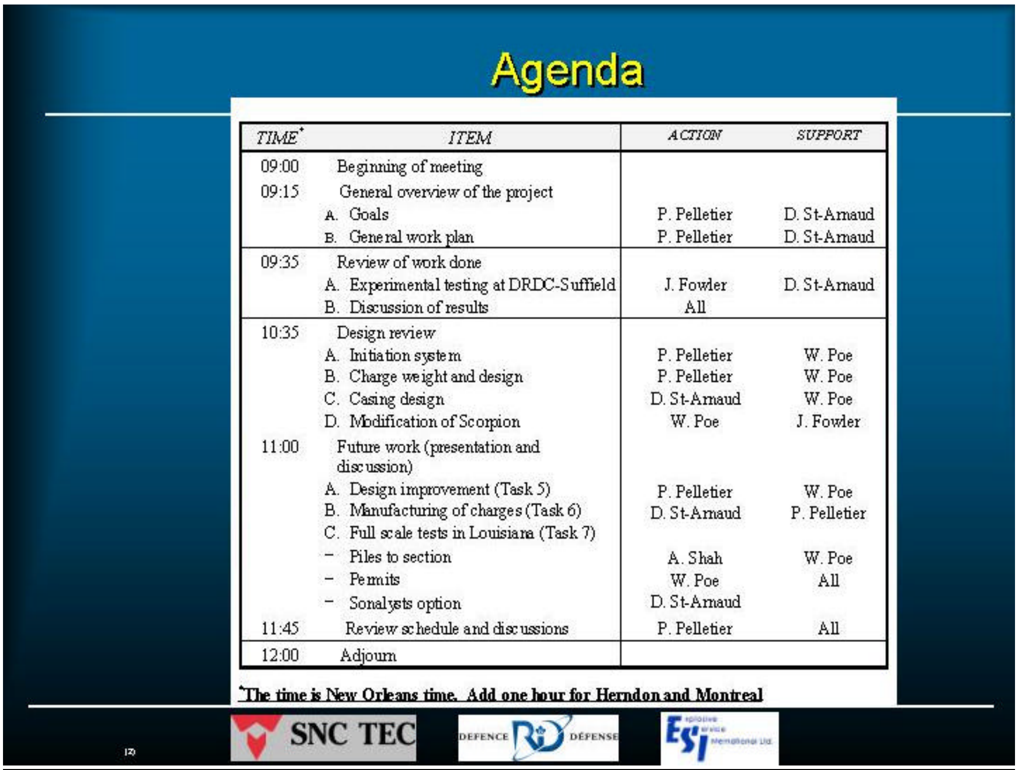
Program Review Meeting Presentation

This Presentation can be found in the Pdf "Program Review Meeting March 24." document. Because of the size of the original powerpoint document (6Mo), it was made a separate entity (Pdf doc of 3Mo) from this meeting report and send independently by e-mail.

Annex C

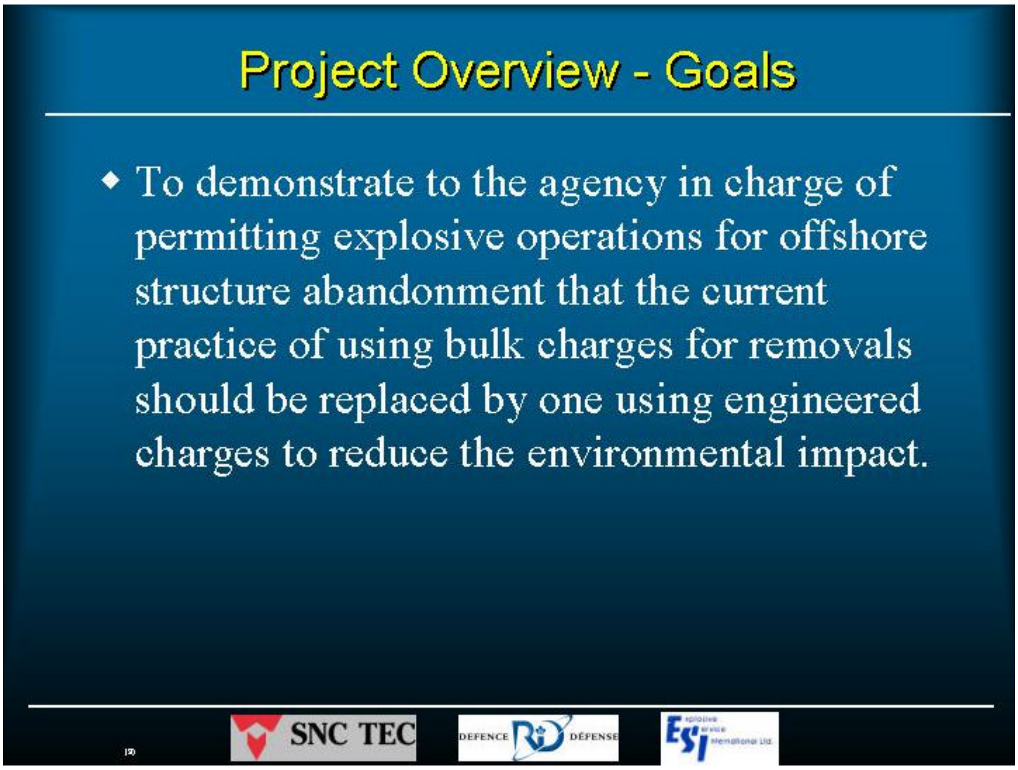
Pjohn Fowler's Presentation Trial Summary

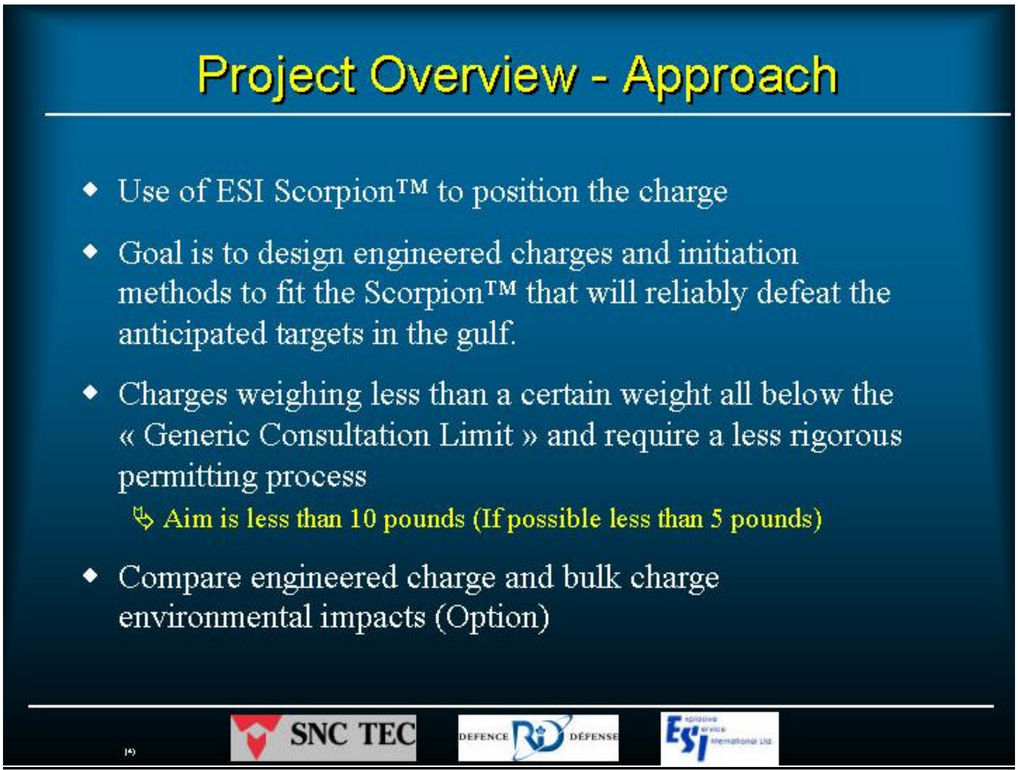
This Presentation can be found in the Pdf "JPF_MMS_SNC_TASK4_" document. Because of the size of the original powerpoint document (13Mo), it was made a separate entity (Pdf doc of 3Mo) from this meeting report and send independently by e-mail.

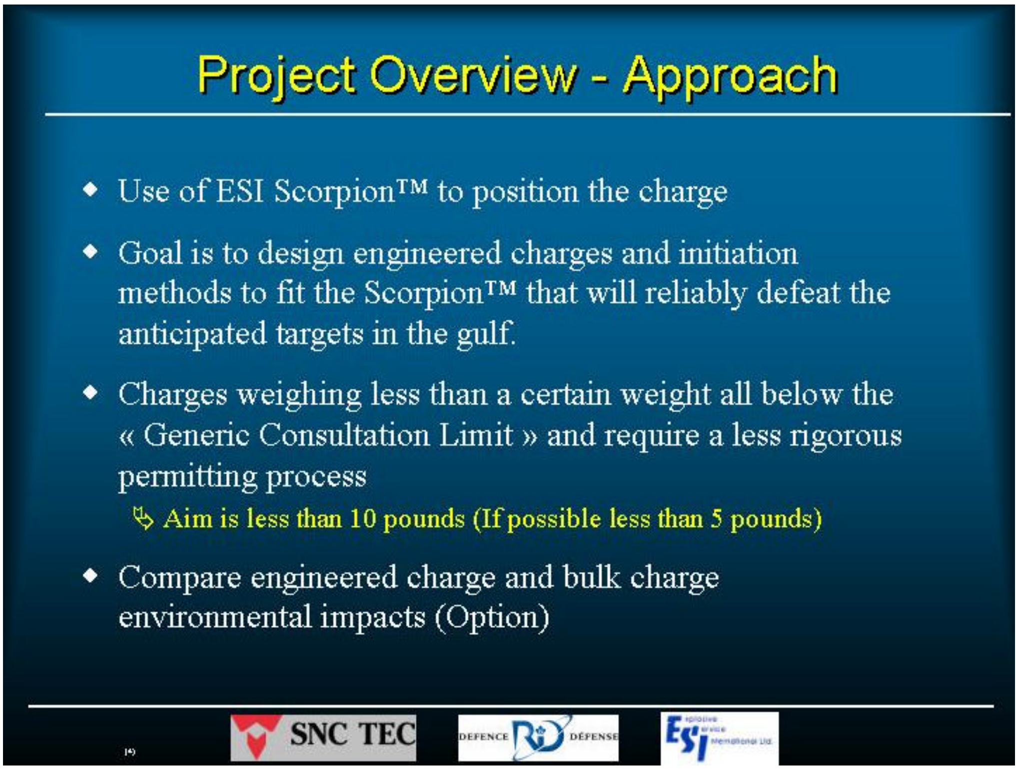


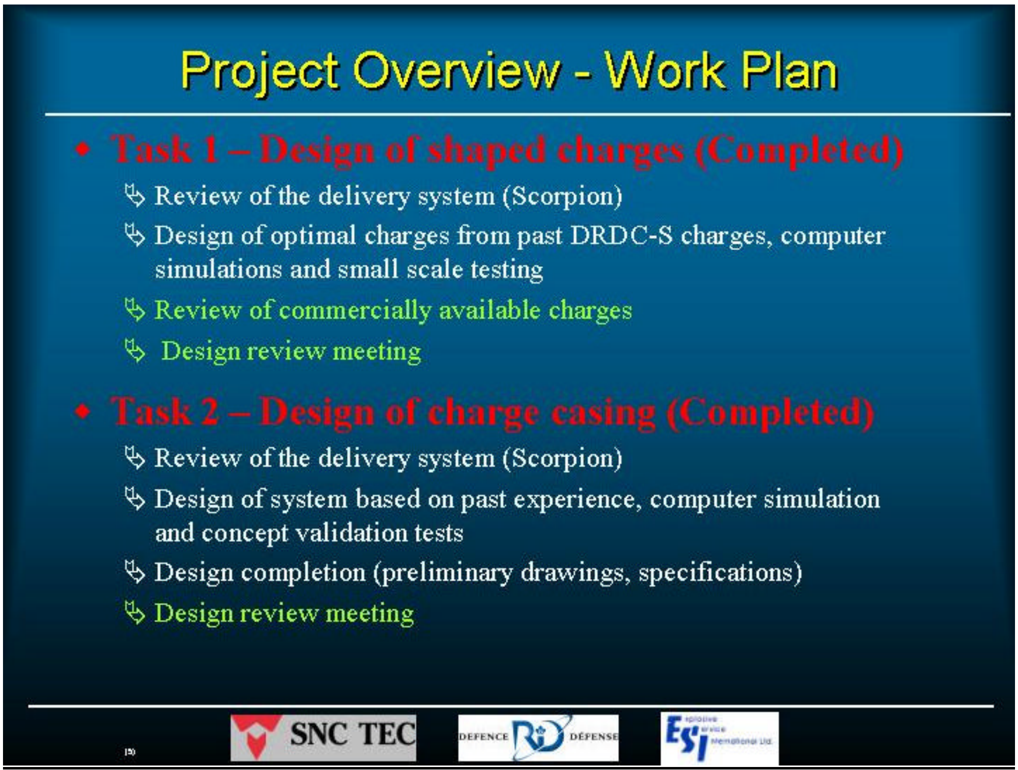
TIME*	ITEM	ACTION	SUPPORT
09:00	Beginning of meeting		
09:15	General overview of the project		
	A. Goals	P. Pelletier	D. St-Arnaud
	B. General work plan	P. Pelletier	D. St-Arnaud
09:35	Review of work done		
	A. Experimental testing at DRDC-Suffield	J. Fowler	D. St-Arnaud
	B. Discussion of results	All	
10:35	Design review		
	A. Initiation system	P. Pelletier	W. Poe
	B. Charge weight and design	P. Pelletier	W. Poe
	C. Casing design	D. St-Arnaud	W. Poe
	D. Modification of Scorpion	W. Poe	J. Fowler
11:00	Future work (presentation and discussion)		
	A. Design improvement (Task 5)	P. Pelletier	W. Poe
	B. Manufacturing of charges (Task 6)	D. St-Arnaud	P. Pelletier
	C. Full scale tests in Louisiana (Task 7)		
	– Piles to section	A. Shah	W. Poe
	– Permits	W. Poe	All
	– Sonalysts option	D. St-Arnaud	
11:45	Review schedule and discussions	P. Pelletier	All
12:00	Adjourn		

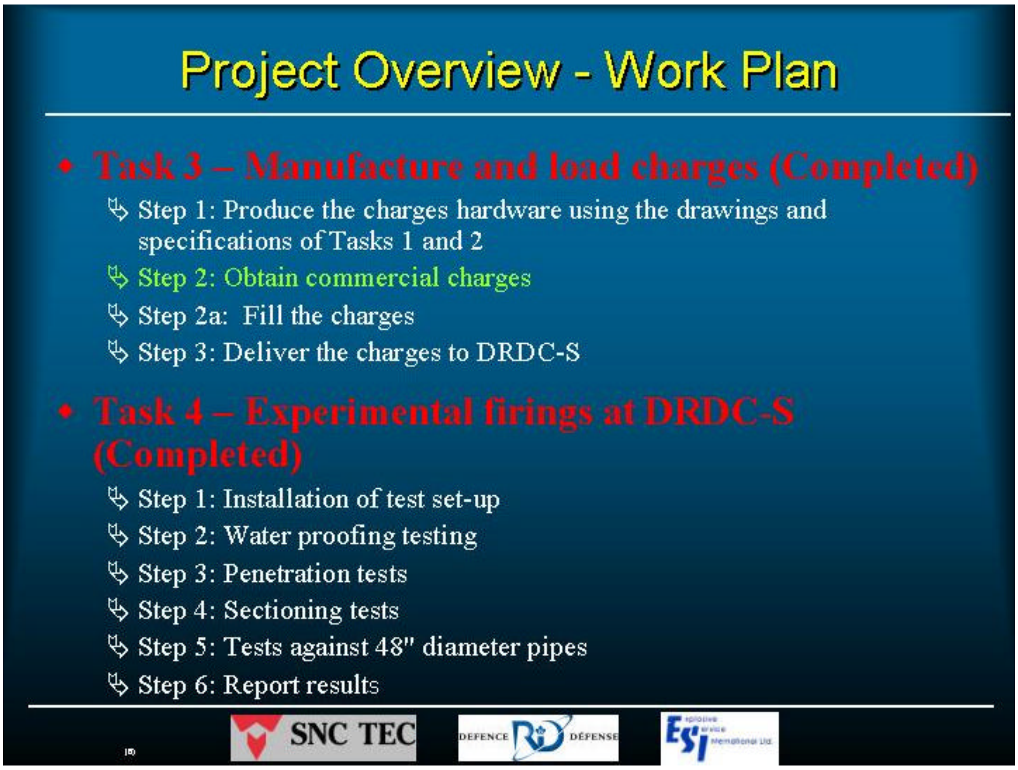
*The time is New Orleans time. Add one hour for Herndon and Montreal

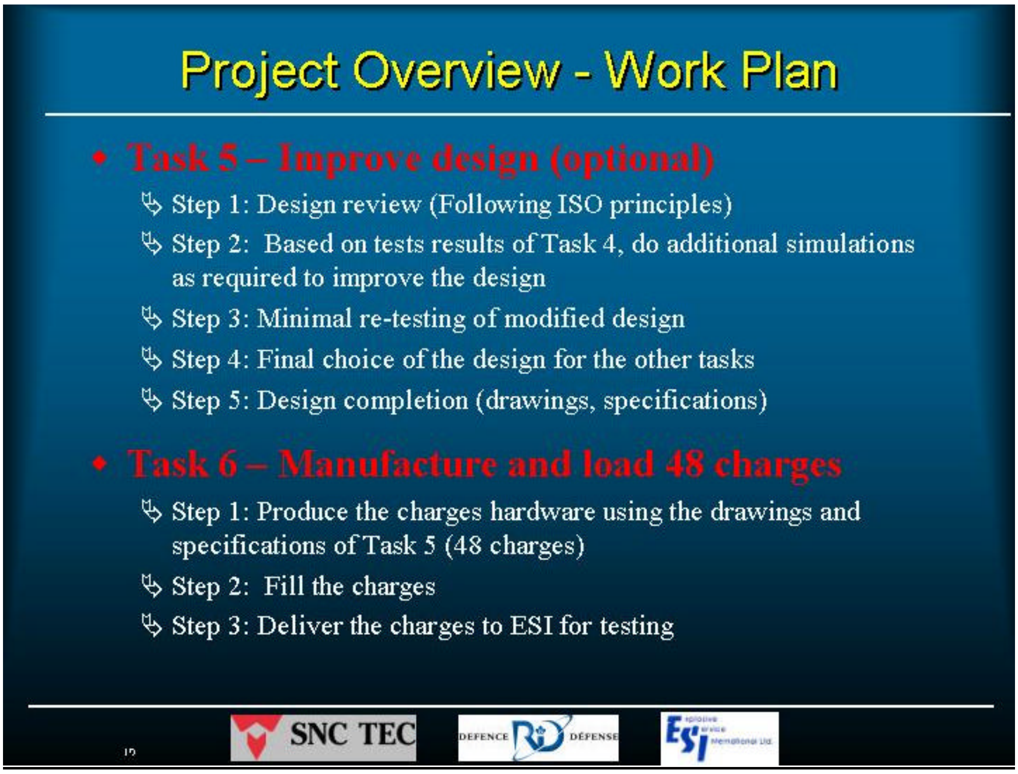

Project Overview - Goals
◆ To demonstrate to the agency in charge of permitting explosive operations for offshore structure abandonment that the current practice of using bulk charges for removals should be replaced by one using engineered charges to reduce the environmental impact.
SNC TEC
DEFENCE
DÉFENSE

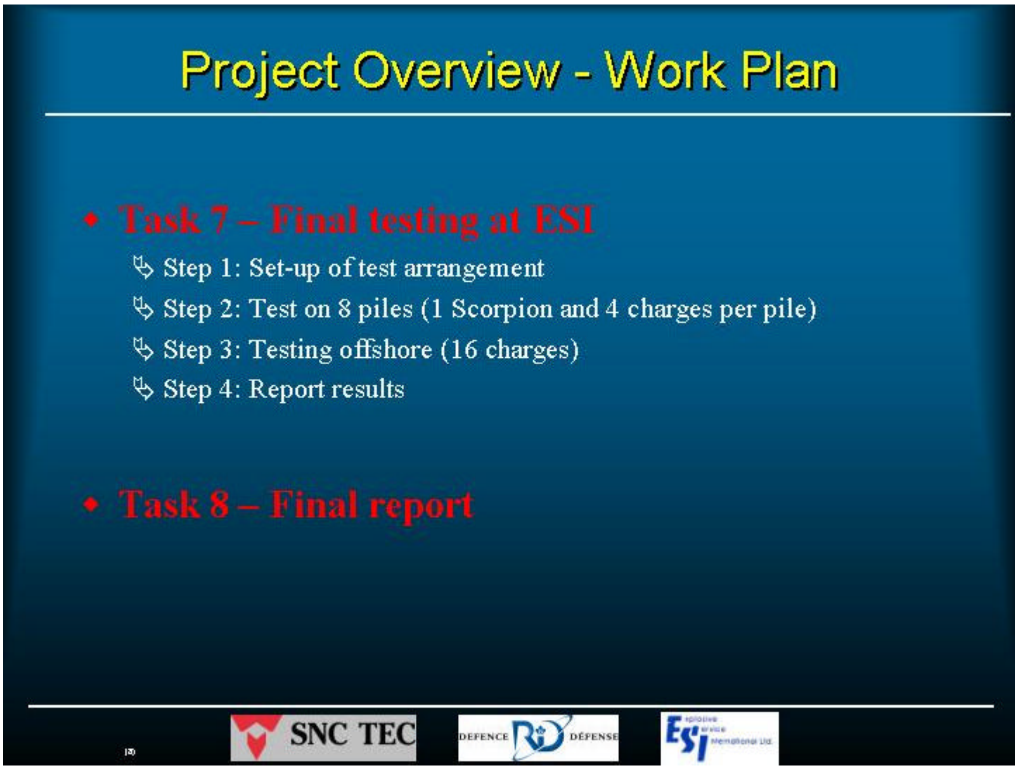

Project Overview - Approach
◆ Use of ESI Scorpion™ to position the charge
◆ Goal is to design engineered charges and initiation methods to fit the Scorpion™ that will reliably defeat the anticipated targets in the gulf.
◆ Charges weighing less than a certain weight all below the « Generic Consultation Limit » and require a less rigorous permitting process
Aim is less than 10 pounds (If possible less than 5 pounds)
◆ Compare engineered charge and bulk charge environmental impacts (Option)
SNC TEC
DEFENCE
DÉFENSE

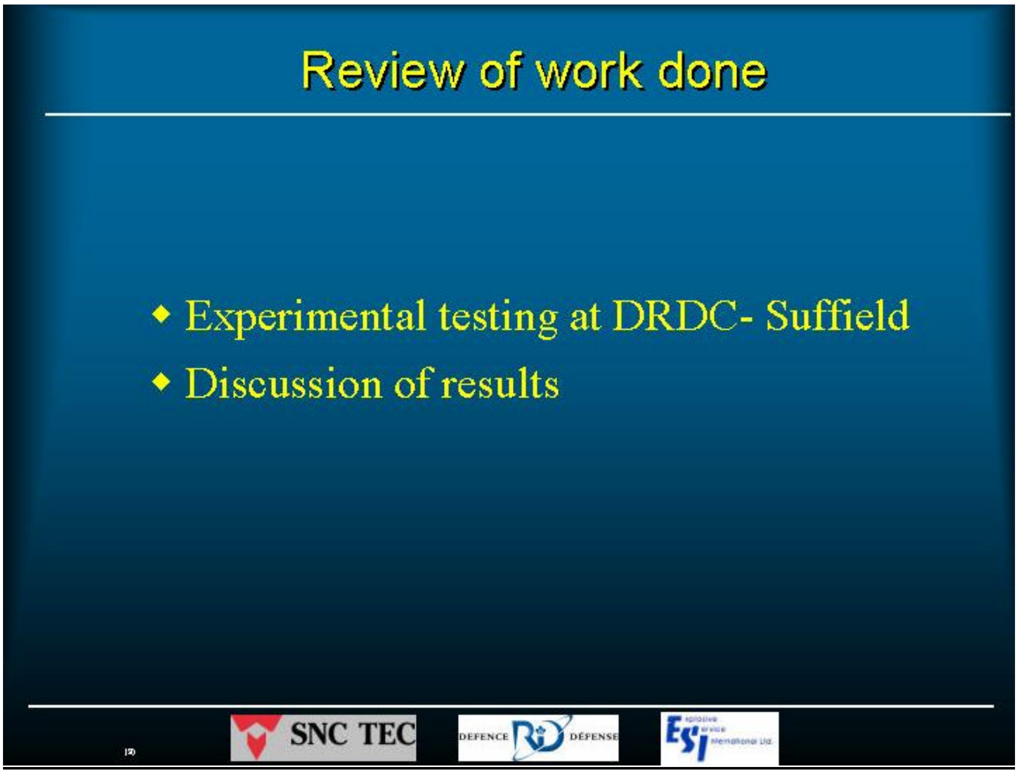

Project Overview - Approach
Use of ESI Scorpion™ to position the charge
Goal is to design engineered charges and initiation methods to fit the Scorpion™ that will reliably defeat the anticipated targets in the gulf.
Charges weighing less than a certain weight all below the « Generic Consultation Limit » and require a less rigorous permitting process
Aim is less than 10 pounds (If possible less than 5 pounds)
Compare engineered charge and bulk charge environmental impacts (Option)

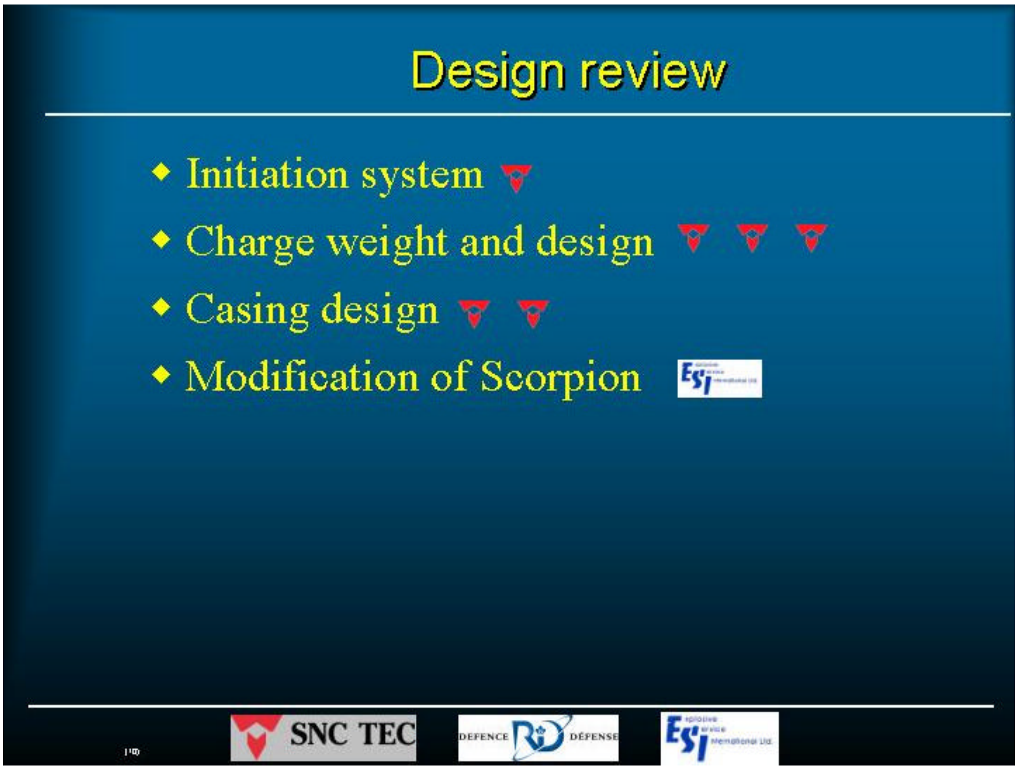

Project Overview - Work Plan
Task 1 – Design of shaped charges (Completed)
Review of the delivery system (Scorpion)
Design of optimal charges from past DRDC-S charges, computer simulations and small scale testing
Review of commercially available charges
Design review meeting
Task 2 – Design of charge casing (Completed)
Review of the delivery system (Scorpion)
Design of system based on past experience, computer simulation and concept validation tests
Design completion (preliminary drawings, specifications)
Design review meeting

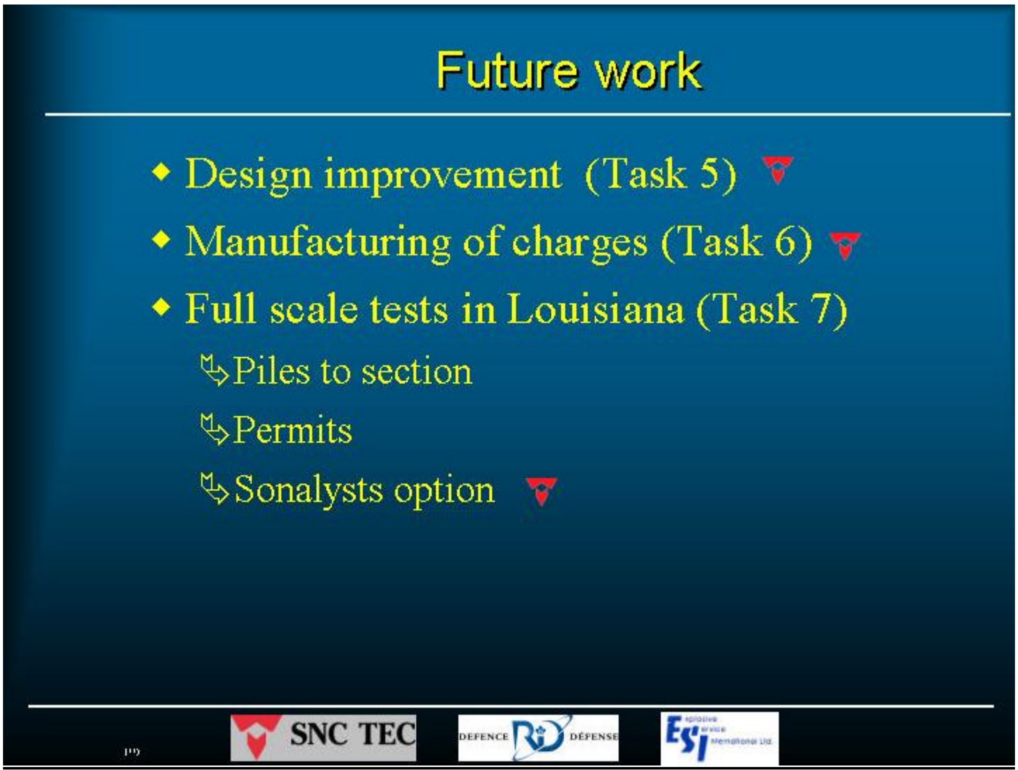

Project Overview - Work Plan
Task 3 – Manufacture and load charges (Completed)
Step 1: Produce the charges hardware using the drawings and specifications of Tasks 1 and 2
Step 2: Obtain commercial charges
Step 2a: Fill the charges
Step 3: Deliver the charges to DRDC-S
Task 4 – Experimental firings at DRDC-S (Completed)
Step 1: Installation of test set-up
Step 2: Water proofing testing
Step 3: Penetration tests
Step 4: Sectioning tests
Step 5: Tests against 48" diameter pipes
Step 6: Report results
SNC TEC
DEFENCE R&D DÉFENSE

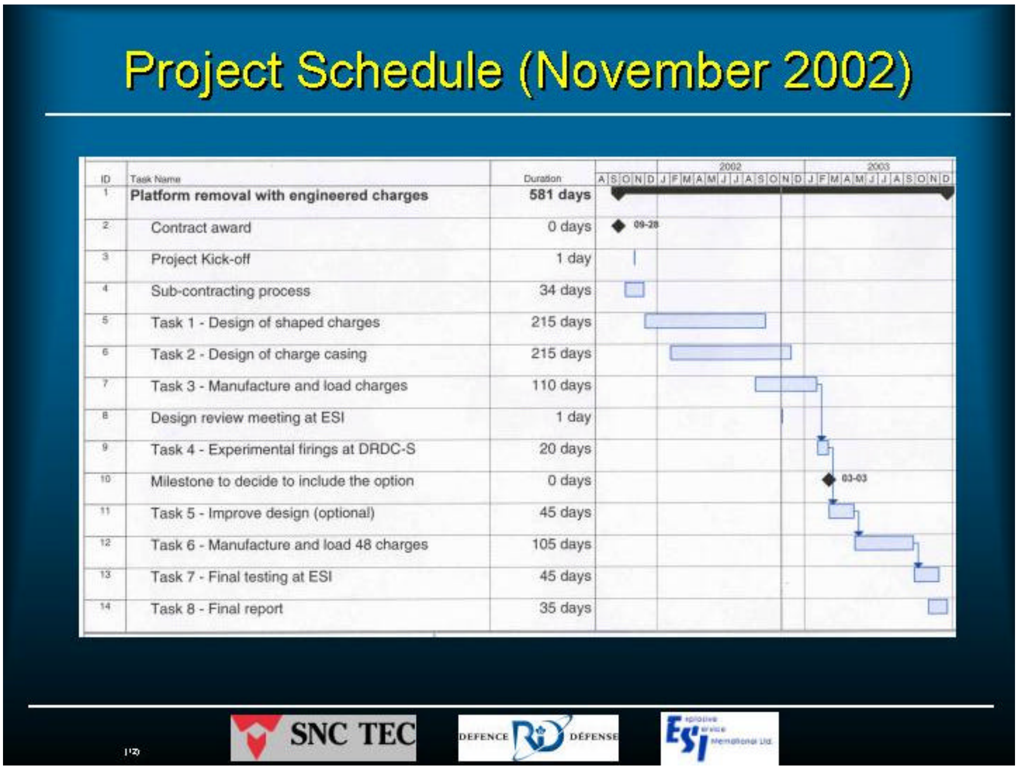

Project Overview - Work Plan
Task 5 – Improve design (optional)
Step 1: Design review (Following ISO principles)
Step 2: Based on tests results of Task 4, do additional simulations as required to improve the design
Step 3: Minimal re-testing of modified design
Step 4: Final choice of the design for the other tasks
Step 5: Design completion (drawings, specifications)
Task 6 – Manufacture and load 48 charges
Step 1: Produce the charges hardware using the drawings and specifications of Task 5 (48 charges)
Step 2: Fill the charges
Step 3: Deliver the charges to ESI for testing
SNC TEC
DEFENCE R&D DÉFENSE


Project Overview - Work Plan
Task 7 – Final testing at ESI
Step 1: Set-up of test arrangement
Step 2: Test on 8 piles (1 Scorpion and 4 charges per pile)
Step 3: Testing offshore (16 charges)
Step 4: Report results
Task 8 – Final report
SNC TEC
DEFENCE
DÉFENSE

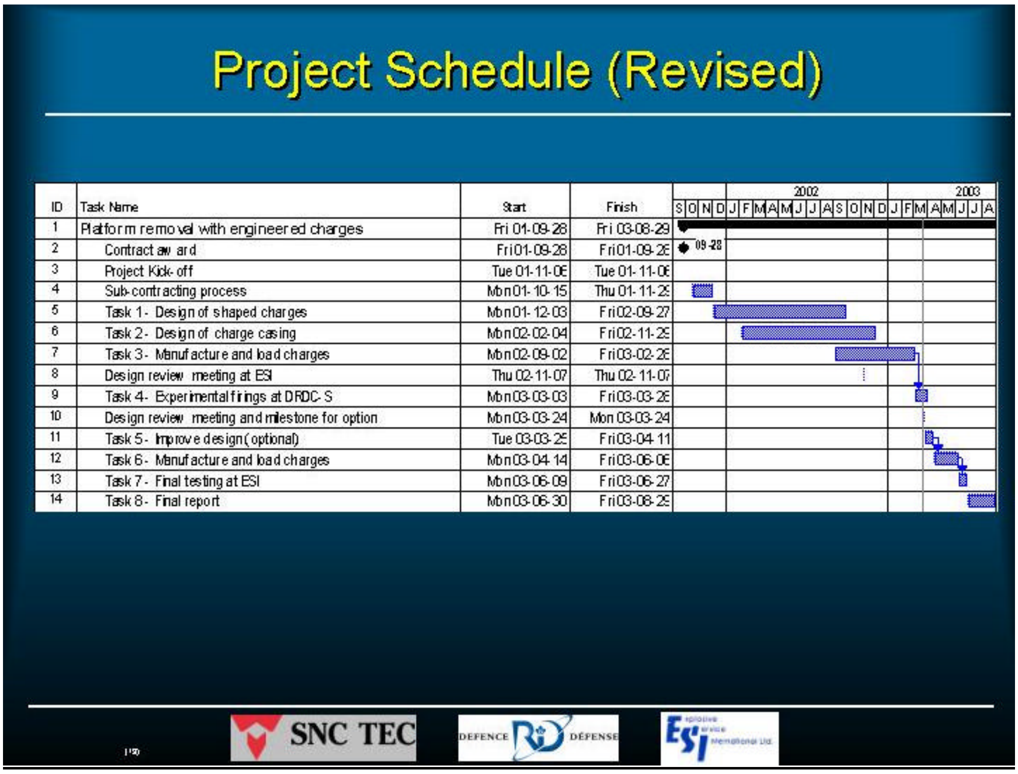

Review of work done
Experimental testing at DRDC- Suffield
Discussion of results
SNC TEC
DEFENCE
DÉFENSE


Design review
Initiation system
Charge weight and design
Casing design
Modification of Scorpion
SNC TEC
DEFENCE
DÉFENSE

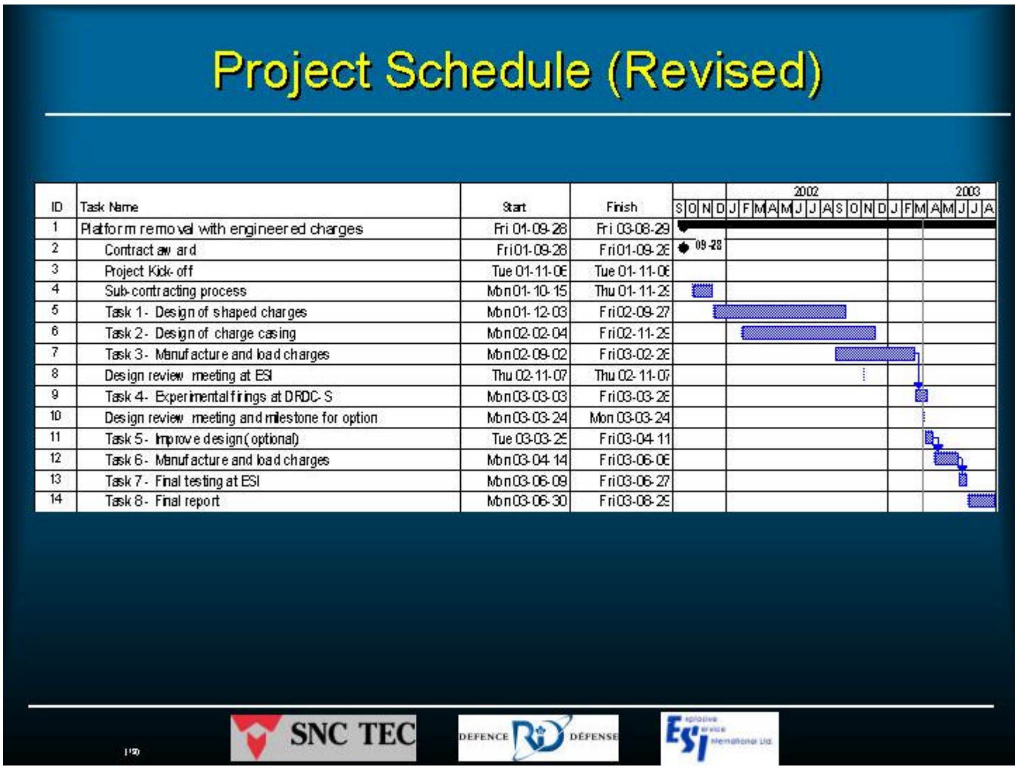

Future work
Design improvement (Task 5)
Manufacturing of charges (Task 6)
Full scale tests in Louisiana (Task 7)
Piles to section
Permits
Sonalysts option
SNC TEC
DEFENCE
DÉFENSE



ID	Task Name	Duration
1	**Platform removal with engineered charges**	**581 days**
2	Contract award	0 days
3	Project Kick-off	1 day
4	Sub-contracting process	34 days
5	Task 1 - Design of shaped charges	215 days
6	Task 2 - Design of charge casing	215 days
7	Task 3 - Manufacture and load charges	110 days
8	Design review meeting at ESI	1 day
9	Task 4 - Experimental firings at DRDC-S	20 days
10	Milestone to decide to include the option	0 days
11	Task 5 - Improve design (optional)	45 days
12	Task 6 - Manufacture and load 48 charges	105 days
13	Task 7 - Final testing at ESI	45 days
14	Task 8 - Final report	35 days



ID	Task Name	Start	Finish
1	Platform removal with engineered charges	Fri 01-09-28	Fri 03-08-29
2	Contract award	Fri 01-09-28	Fri 01-09-28
3	Project Kick-off	Tue 01-11-06	Tue 01-11-06
4	Sub-contracting process	Mon 01-10-15	Thu 01-11-29
5	Task 1 - Design of shaped charges	Mon 01-12-03	Fri 02-09-27
6	Task 2 - Design of charge casing	Mon 02-02-04	Fri 02-11-29
7	Task 3 - Manufacture and load charges	Mon 02-09-02	Fri 03-02-28
8	Design review meeting at ESI	Thu 02-11-07	Thu 02-11-07
9	Task 4 - Experimental firings at DRDC-S	Mon 03-03-03	Fri 03-03-28
10	Design review meeting and milestone for option	Mon 03-03-24	Mon 03-03-24
11	Task 5 - Improve design (optional)	Tue 03-03-25	Fri 03-04-11
12	Task 6 - Manufacture and load charges	Mon 03-04-14	Fri 03-06-06
13	Task 7 - Final testing at ESI	Mon 03-06-09	Fri 03-06-27
14	Task 8 - Final report	Mon 03-06-30	Fri 03-08-29



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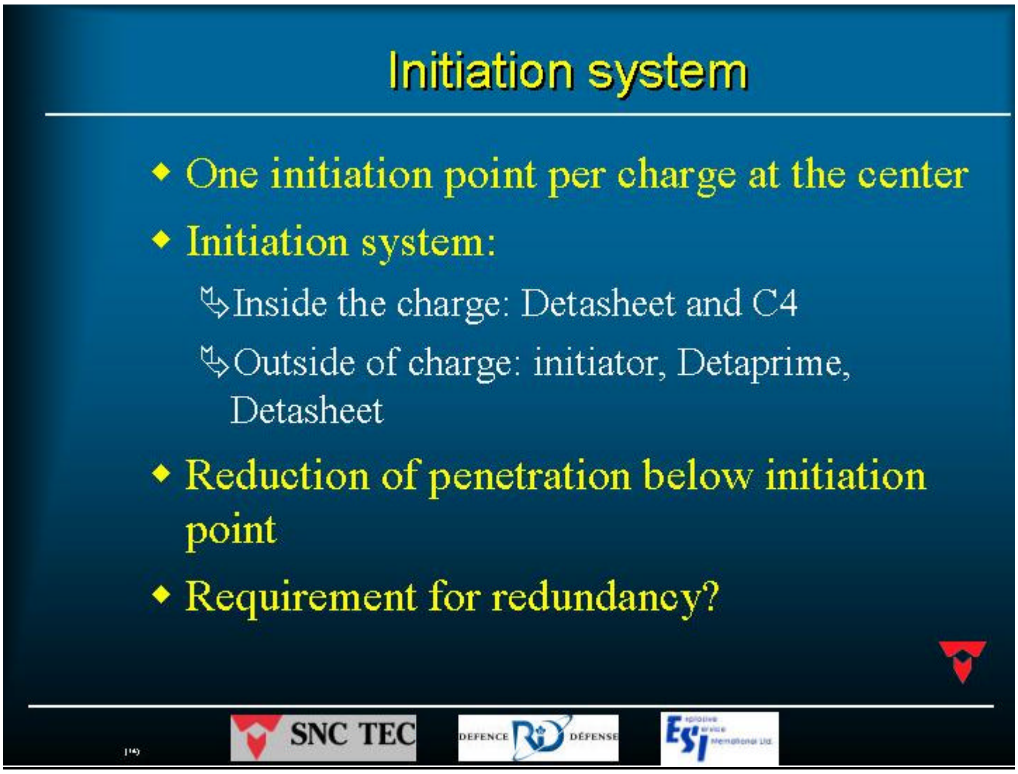
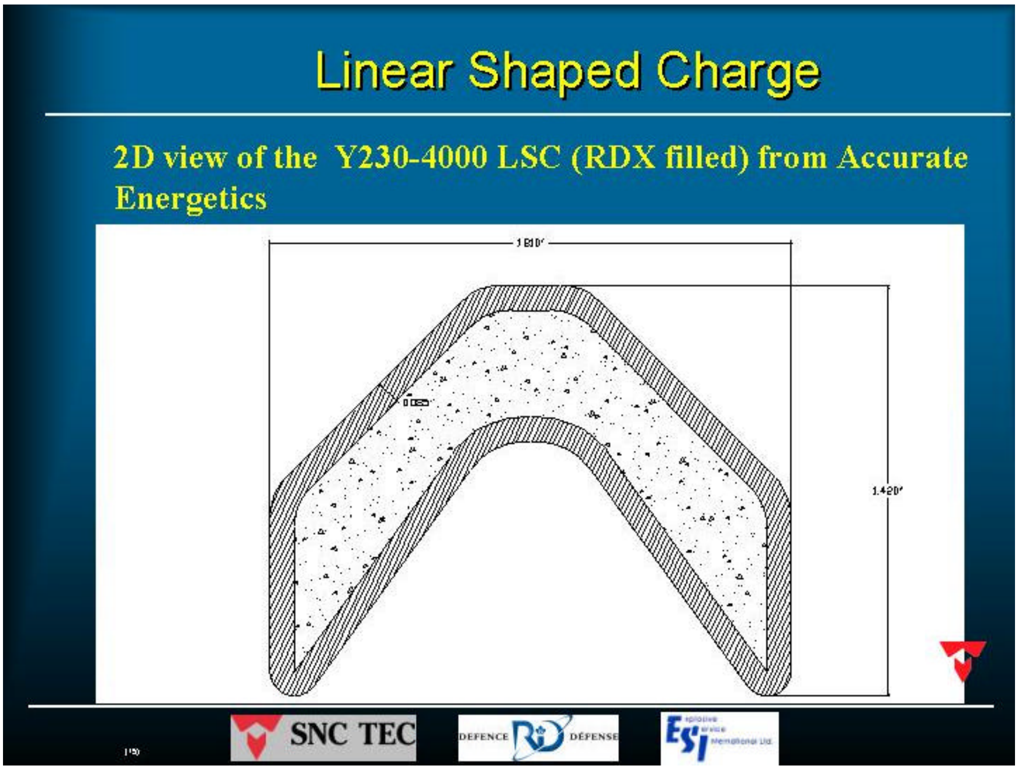
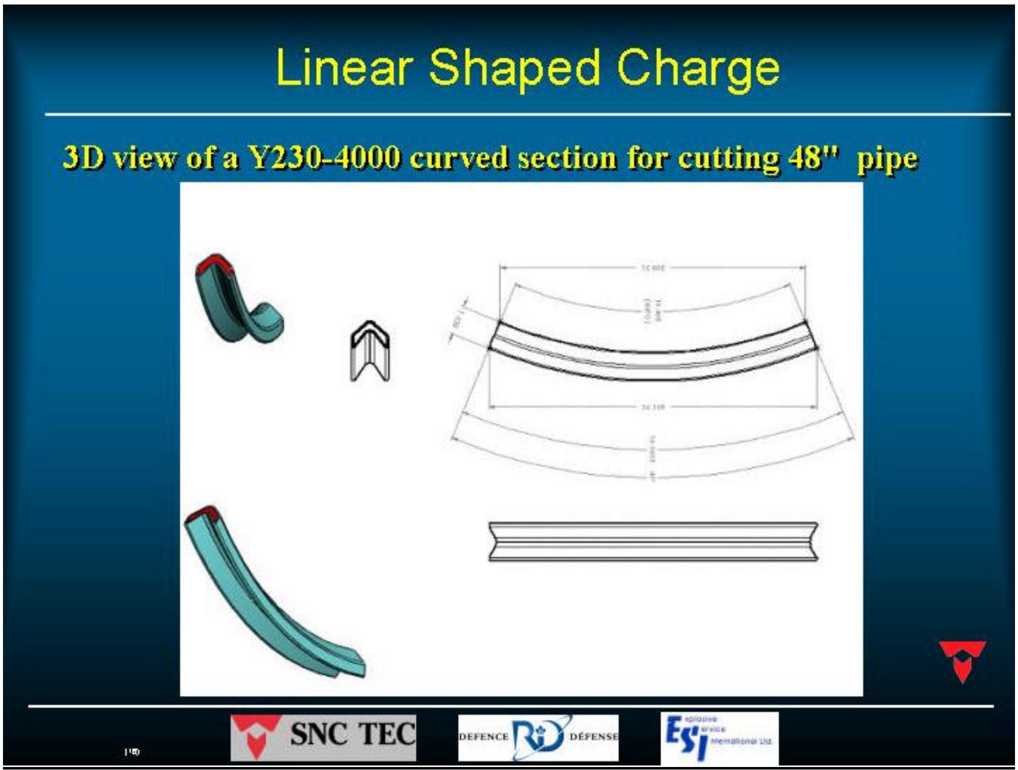
11	Task 5 - Improve design (optional)	Tue 03-03-25	Fri 03-04-11
12	Task 6 - Manufacture and load charges	Mon 03-04-14	Fri 03-06-06
13	Task 7 - Final testing at ESI	Mon 03-06-09	Fri 03-06-27
14	Task 8 - Final report	Mon 03-06-30	Fri 03-08-29




Linear Shaped Charge
2D view of the Y230-4000 LSC (RDX filled) from Accurate Energetics
1.420"
SNC TEC
DEFENCE
DÉFENSE


Linear Shaped Charge
3D view of a Y230-4000 curved section for cutting 48" pipe
SNC TEC
DEFENCE
DÉFENSE

Linear Shaped Charge

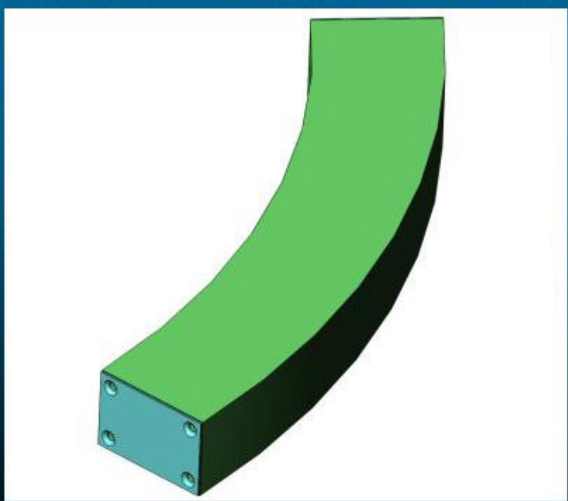
Total charge mass for sectioning different piles sizes

Pile diameter	With overlap	w/o overlap
48	6.64 lbs	6.35 lbs
36	4.92 lbs	4.64 lbs
30	4.11 lbs	3.80 lbs
24	3.20 lbs	2.92 lbs

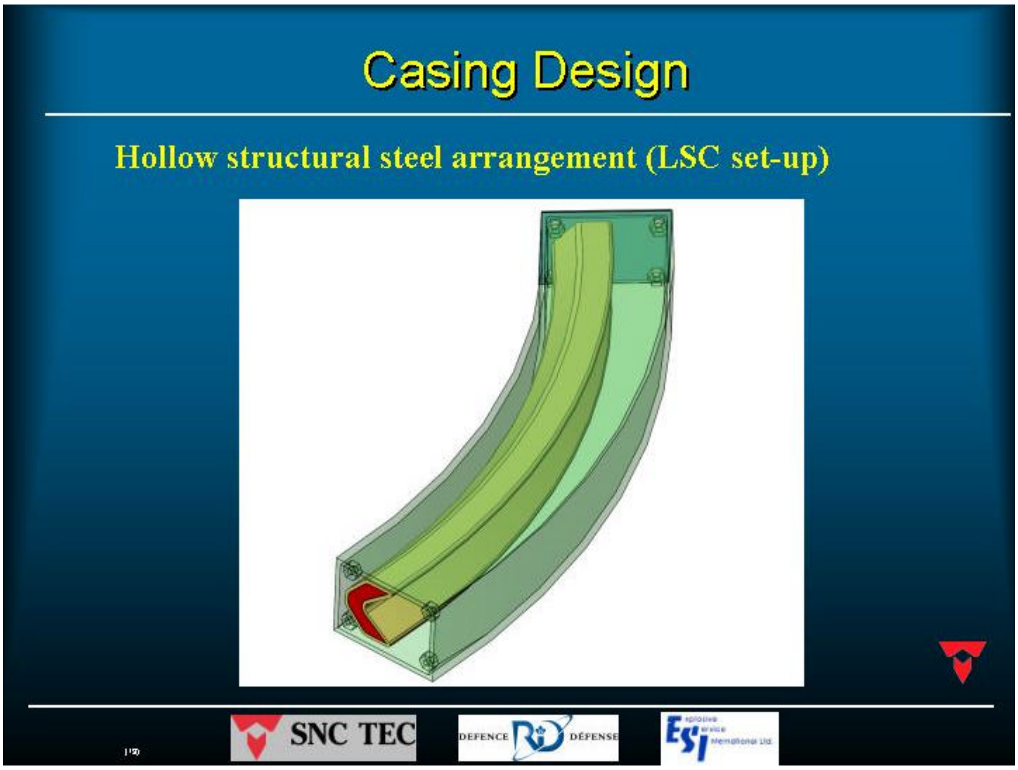
SNC TEC DEFENCE R&D DÉFENSE

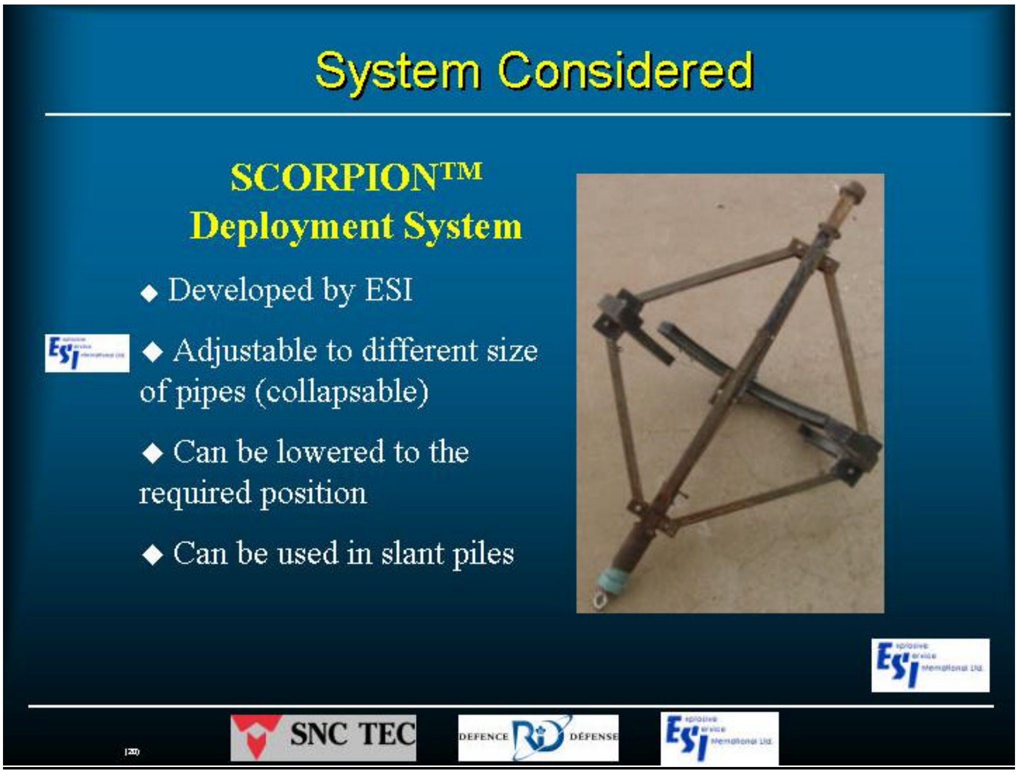
Casing Design

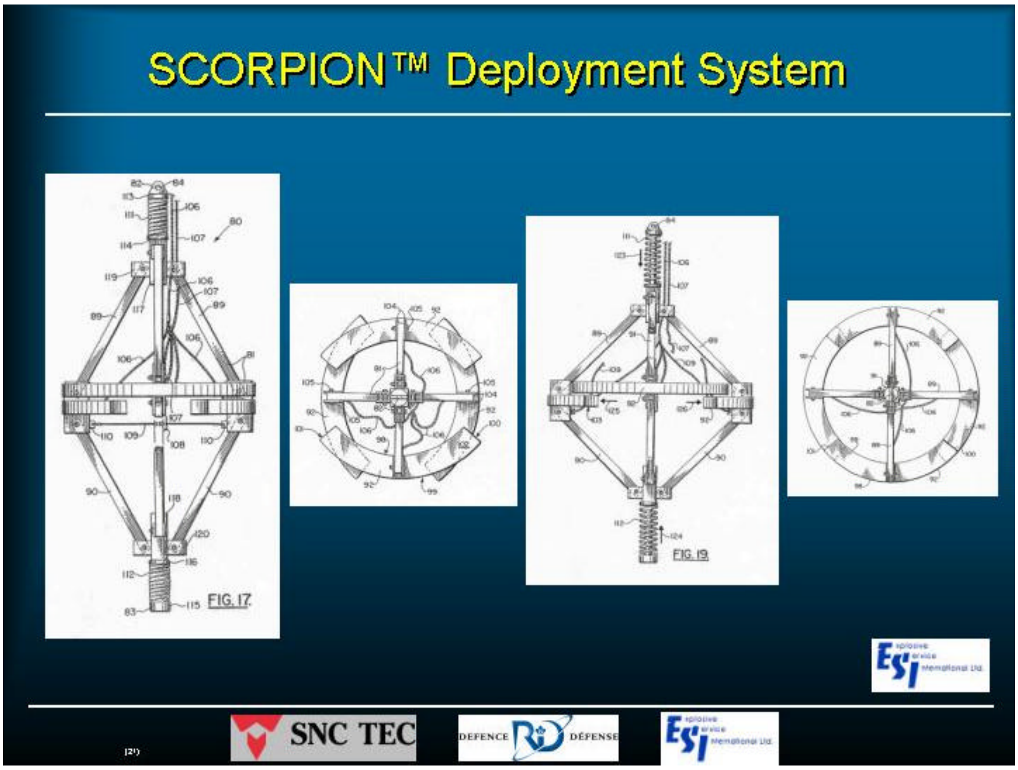
Hollow structural steel design (water tightness)

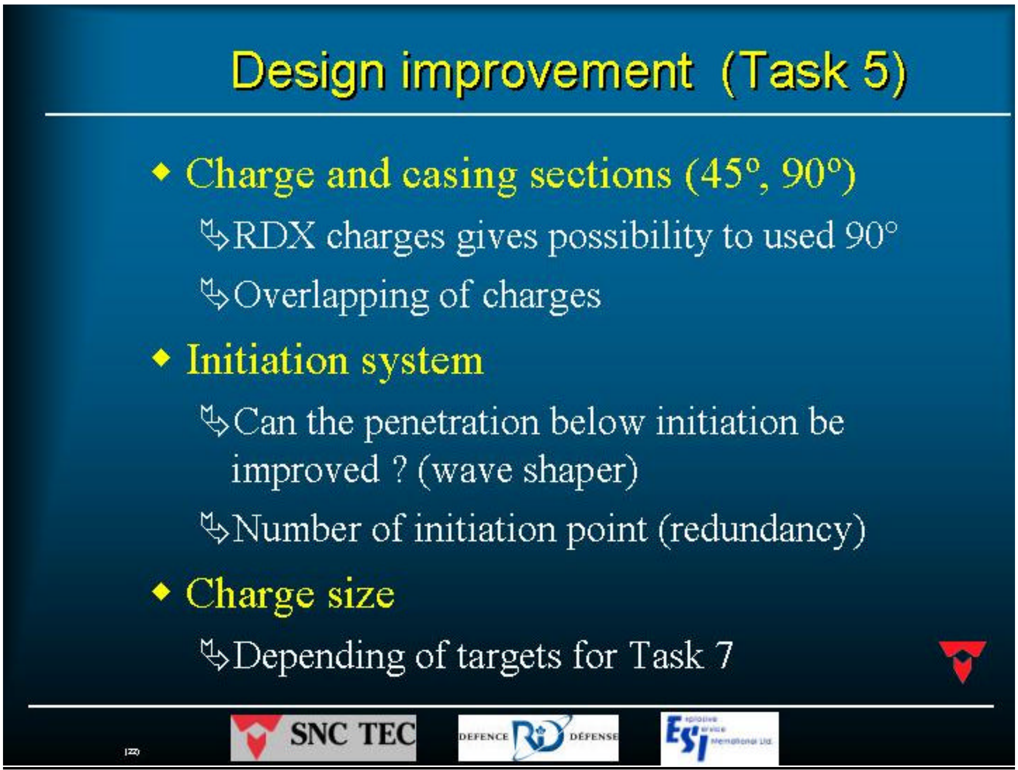


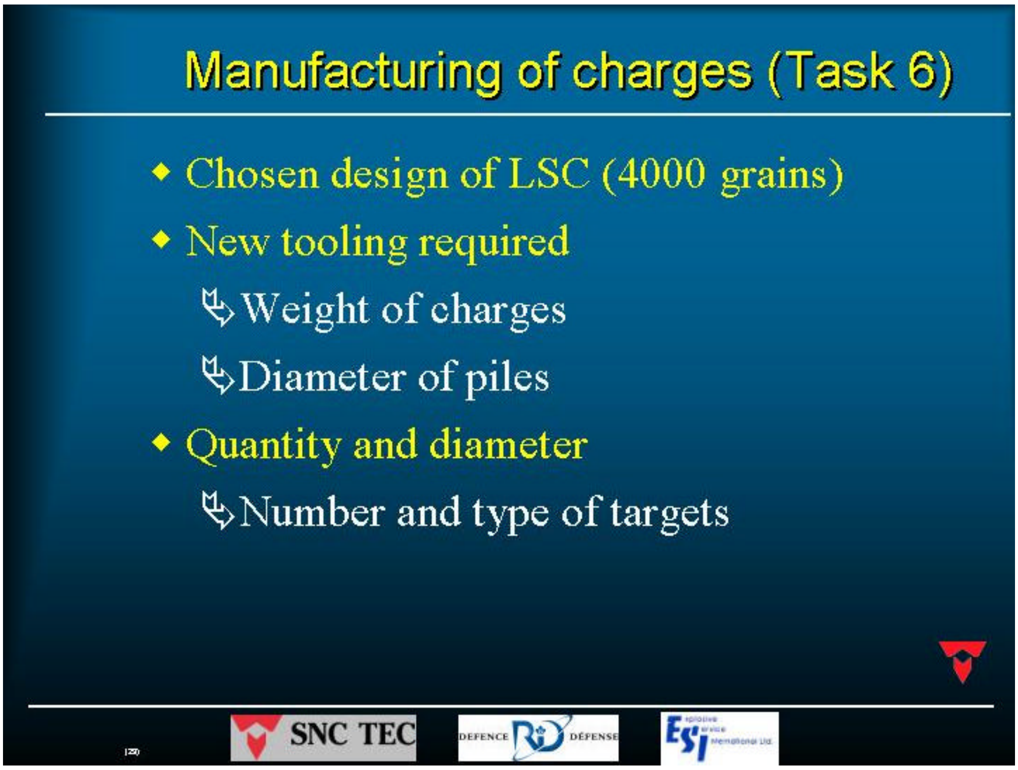
SNC TEC DEFENCE R&D DÉFENSE

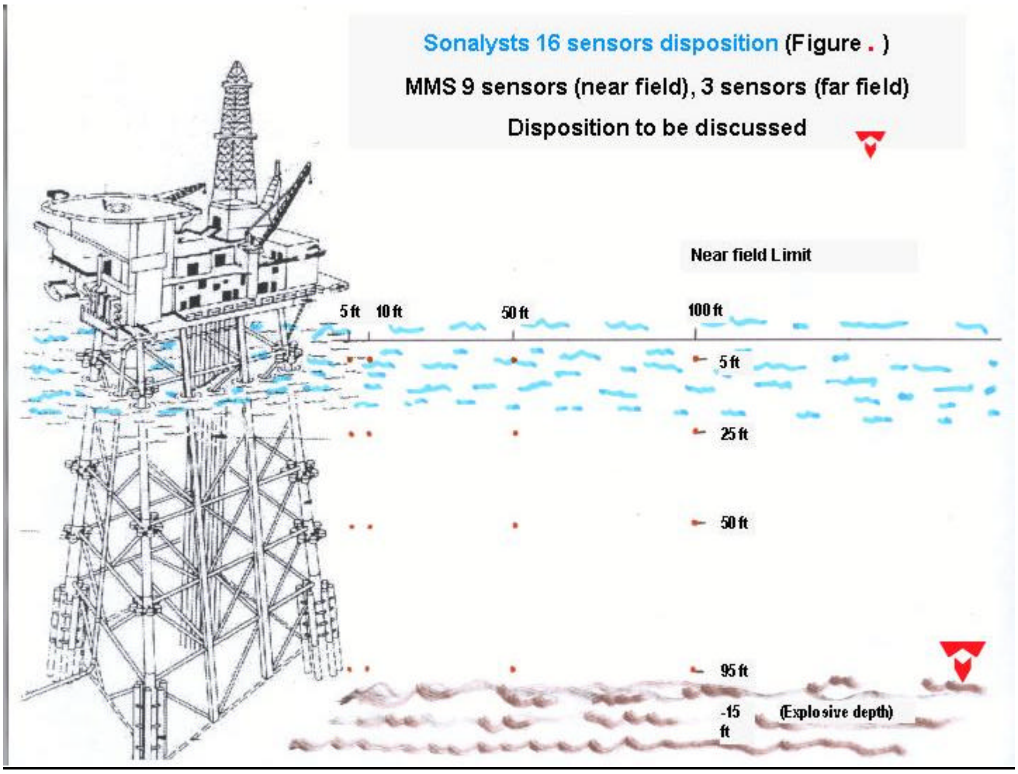

Casing Design
Hollow structural steel arrangement (LSC set-up)
SNC TEC
DEFENCE
DÉFENSE

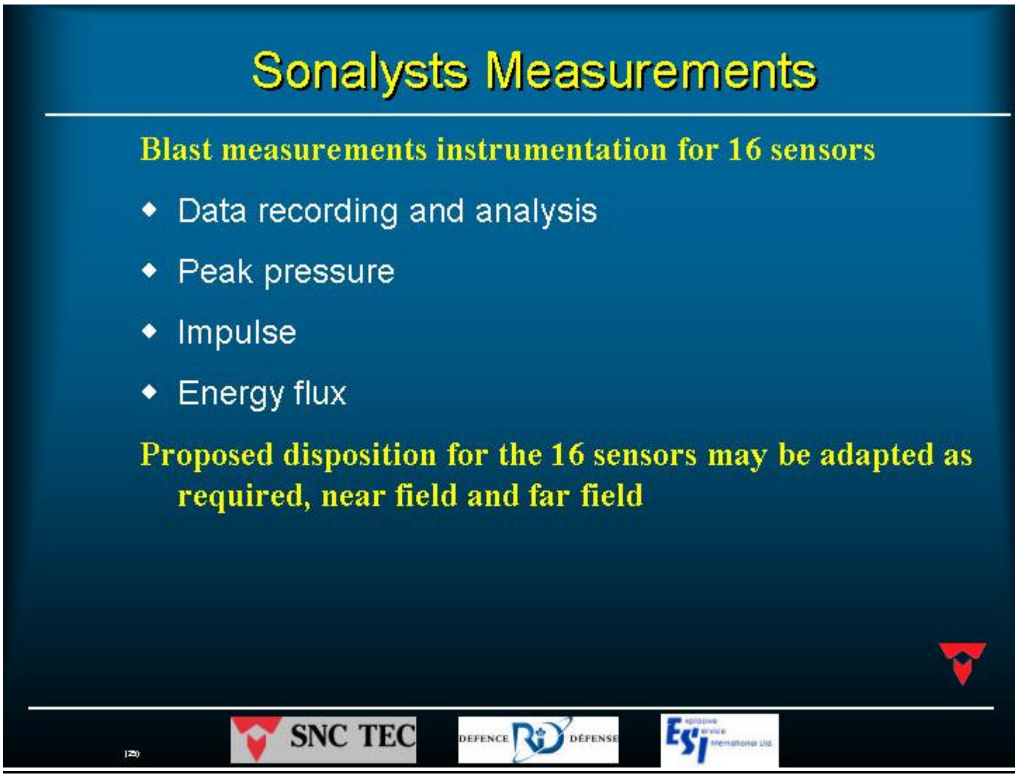

System Considered
SCORPION™
Deployment System
◆ Developed by ESI
◆ Adjustable to different size of pipes (collapsable)
◆ Can be lowered to the required position
◆ Can be used in slant piles
SNC TEC
DEFENCE
DÉFENSE

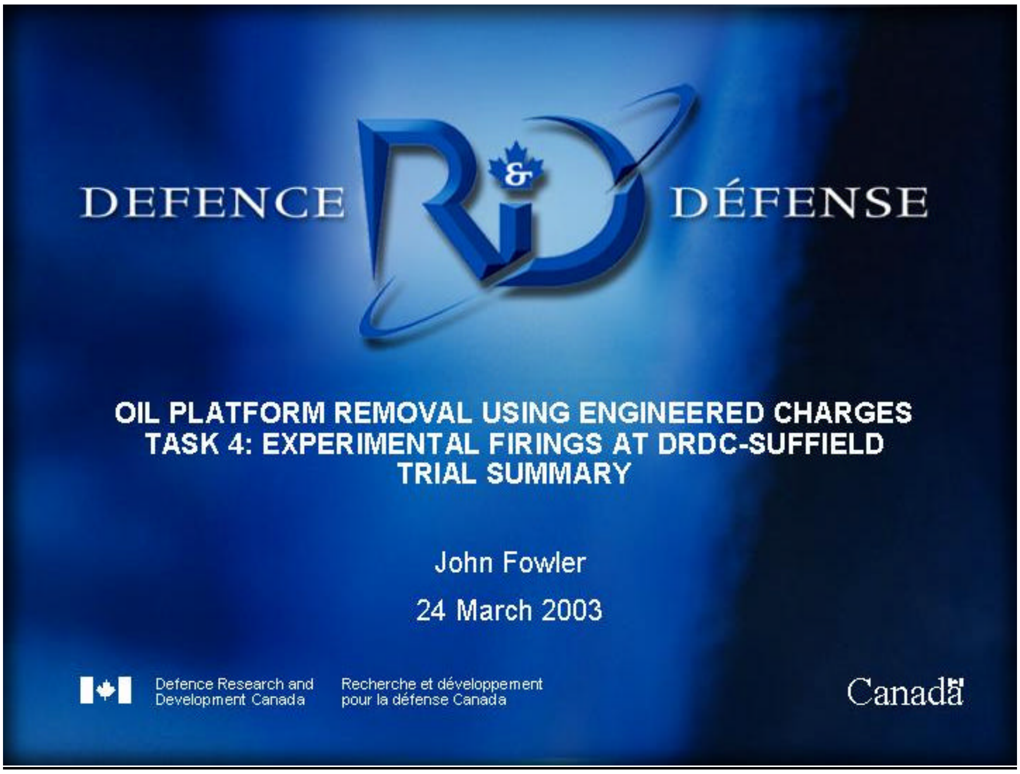

SCORPION™ Deployment System
FIG. 17
FIG. 19
SNC TEC
DEFENCE
DÉFENSE


Design improvement (Task 5)
◆ Charge and casing sections (45°, 90°)
↳RDX charges gives possibility to used 90°
↳Overlapping of charges
◆ Initiation system
↳Can the penetration below initiation be improved ? (wave shaper)
↳Number of initiation point (redundancy)
◆ Charge size
↳Depending of targets for Task 7
SNC TEC
DEFENCE
DÉFENSE


Manufacturing of charges (Task 6)
Chosen design of LSC (4000 grains)
New tooling required
Weight of charges
Diameter of piles
Quantity and diameter
Number and type of targets
SNC TEC
DEFENCE
DÉFENSE


Sonalysts 16 sensors disposition (Figure .)
MMS 9 sensors (near field), 3 sensors (far field)
Disposition to be discussed
Near field Limit
5 ft
10 ft
50 ft
100 ft
5 ft
25 ft
50 ft
95 ft
-15 ft
(Explosive depth)


Sonalysts Measurements
Blast measurements instrumentation for 16 sensors
Data recording and analysis
Peak pressure
Impulse
Energy flux
Proposed disposition for the 16 sensors may be adapted as required, near field and far field
SNC TEC
DEFENCE
DÉFENSE

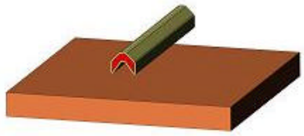

DEFENCE R&D DÉFENSE
OIL PLATFORM REMOVAL USING ENGINEERED CHARGES
TASK 4: EXPERIMENTAL FIRINGS AT DRDC-SUFFIELD
TRIAL SUMMARY
John Fowler
24 March 2003
Defence Research and Development Canada
Recherche et développement pour la défense Canada
Canada

Trial Plan

Table #1 : Linear shape charge straight
To compare data of commercial shape charge with previous data of optimized charge

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
1 & 2	RDX	Straight charge 12" long	Not applicable	1.25 inches	Target steel plate Electric initiator	Two

- Target plate 1.5 inch mild steel plate.
- Plate will be water backed to provide appropriate boundary conditions.
- Initiation using PRIMADET(MS) with C4 booster to ensure contact.



- The plate will be sectioned to evaluate damage.

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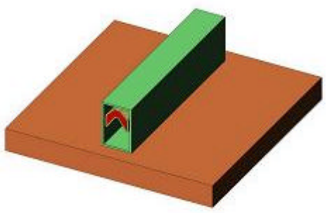
Trial Plan

Table #2 : Linear shape charge straight
To validate charge comportment in immersed casing

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
3 & 4	RDX	Straight charge 12" long	Straight 12" long	1.25 inches	Target steel plate, Electric initiator, pool and water	Two

- Target plate 1.5 inch mild steel plate.
- Plate and steel casing enclosing charge will be submerged.
- Initiation may be a challenge.



- The plate will be sectioned to evaluate damage.

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Trial Plan

Table #3 : Linear shape charge curved with casing
To validate commercial charge comportment in immersed casing against a target simuling a pile section

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
5	RDX	Curved charge 16" long	Curved 16" long	1.25 inches	Target steel pipe section, Electric initiator, pool and water	Three

- Target is 48" diameter pile.
- The charge and pile will be submerged.
- The plate will be sectioned to evaluate damage.
- Assess submerged and staggered charges for cutting pile.

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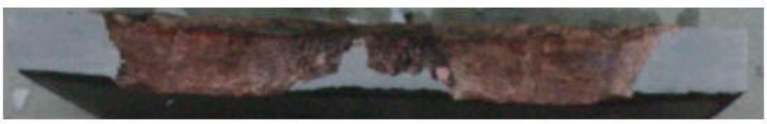
Trial 1 : Linear Charge with Water Backing

- Twelve-inch RDX charge.
- Mild steel plate (1.5 in).
- Water backing.
- Partial perforation
  - lower penetration under detonator.



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Trial 2 : Linear Charge with Sand Backing
• Twelve-inch RDX charge.
• Mild steel plate (1.5 in).
• Saturated sand backing.
• Partial perforation
– performance similar to water backed charge.
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Trials 3-7 : Initiation Testing
• Initiation tests were performed to ensure that detonation would be achieved through the steel case.
• With a vertical detonator a 3/8” deep C4 well, 5/8” in diameter with a 5/8” diameter disk of 1/8” detasheet initiated a similar detasheet disk below a 1/16” steel plate.
• A horizontal detonator placement required a 5 gram detaprime booster on the 5/8” detasheet disk to initiate the similar detasheet disk below a 1/16” steel plate.
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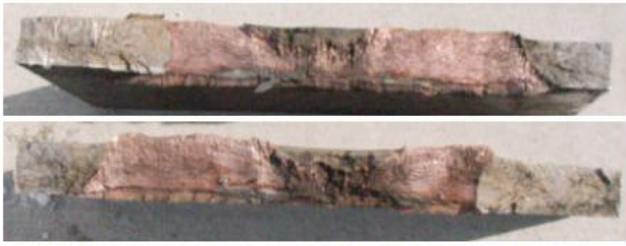
Trial 8 : Water Backed Linear Charge

- A layer of 1/8” detasheet was added to the top of the charge to improve penetration under the detonator.
- Penetration was similar to trials 1 and 2. The additional explosive did fracture the plate below the detonator.



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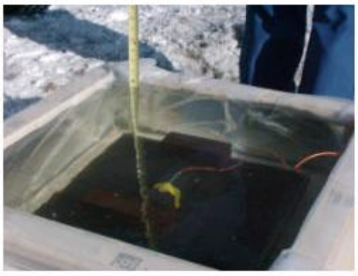
Trial 9 : Cased Linear Charge Submerged

- Twelve-inch RDX charge.
- Mild steel plate (1.5 in).
- Submerged cased charge.
- Initiation donor system failed to detonate charge through the steel casing.



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Trial 10 : Dual Initiation

- The benefit of colliding detonation waves on shaped charge performance was addressed.
- As noted in earlier trials on smaller charges, the benefit is a localized effect.

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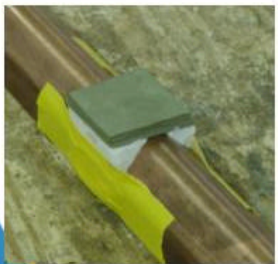
Trial 11 : Cased Linear Charge

- Based on the previous cased trial a more robust initiation system was utilized.
  - C4 and detasheet acceptor charge.
  - Detasheet and primadet donor charge.
  - Spring to hold charge in place.



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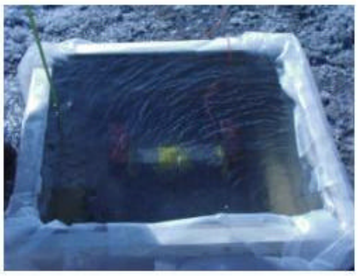
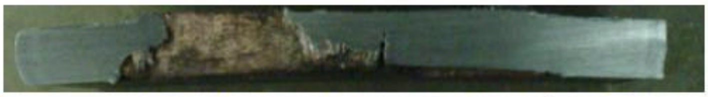
Trial 11 : Submerged Backing

- Twelve-inch RDX charge.
- Mild steel plate (1.5 in).
- Submerged cased charge.
- The charge was initiated through the steel casing. Penetration suggests initiation occurred on only one side of the charge.





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Trial 12 : Curved Charge with Air Backing

- Fourteen-inch curved RDX charge.
- Pile material target.
- Air backed.

- The charge was properly initiated through the steel casing.

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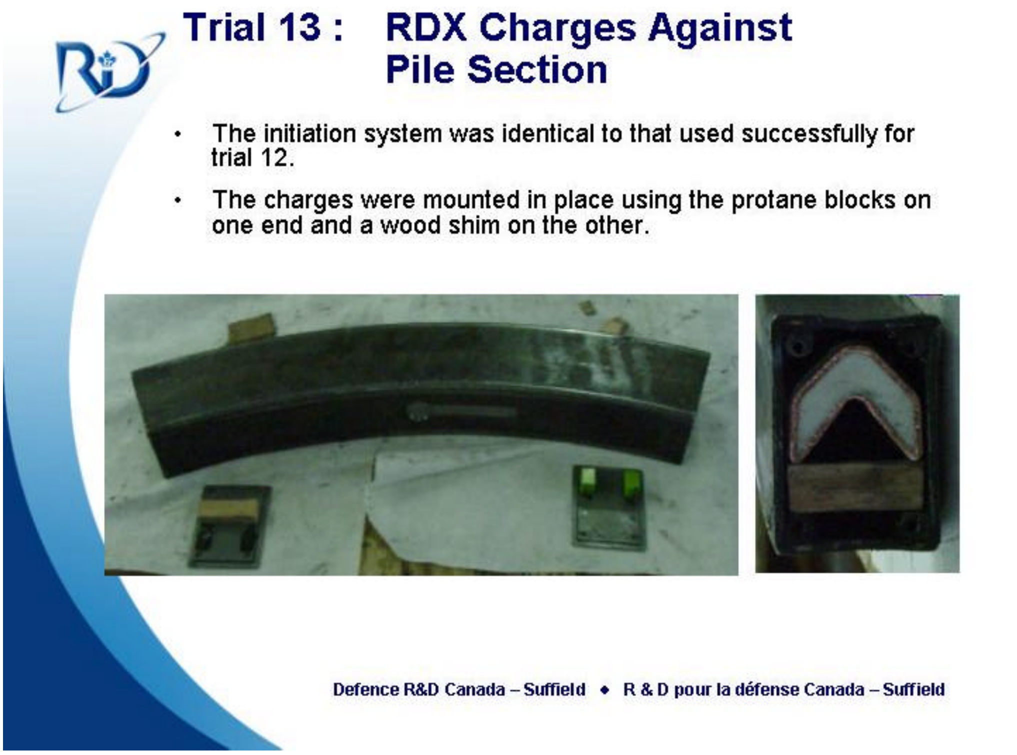
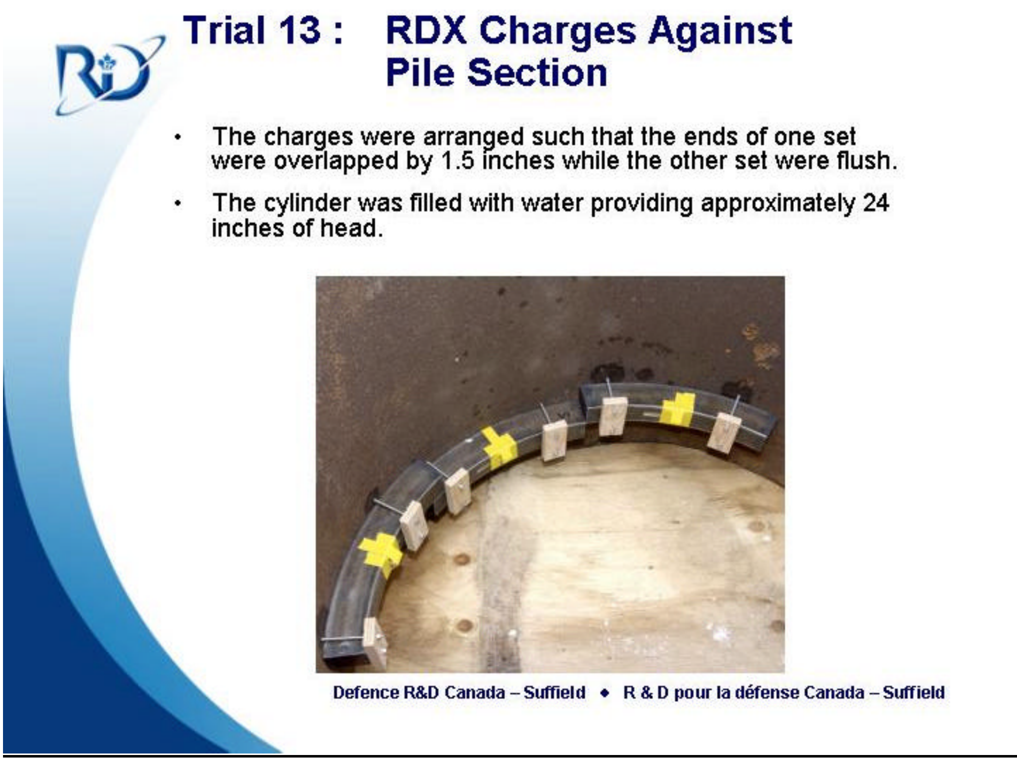

Trial 13 : RDX Charges Against Pile Section
• The initiation system was identical to that used successfully for trial 12.
• The charges were mounted in place using the protane blocks on one end and a wood shim on the other.
Defence R&D Canada – Suffield ◆ R & D pour la défense Canada – Suffield


Trial 13 : RDX Charges Against Pile Section
• The charges were arranged such that the ends of one set were overlapped by 1.5 inches while the other set were flush.
• The cylinder was filled with water providing approximately 24 inches of head.
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Trial 13 : RDX Charges Against Pile Section

- The charges successfully detonated and penetrated the pile.
- Cracking occurred between the cutting planes.
- Two cracks propagated from the intersection plane of the flush charges.

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Trial 13 : RDX Charges Against Pile Section

- Perforation did not occur under the detonator for one of the charges.
- The cracks between the cutting planes are clearly shown.
- The two cracks running from where the charges meet is a characteristic event that has been noted on several shots performed by ESI.

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Trial 14 : Curved Charge with Air Backing

- Fourteen-inch curved Composition-B charge.
- Pile material target.
- Air backed.

- The charge was properly initiated through the steel casing.

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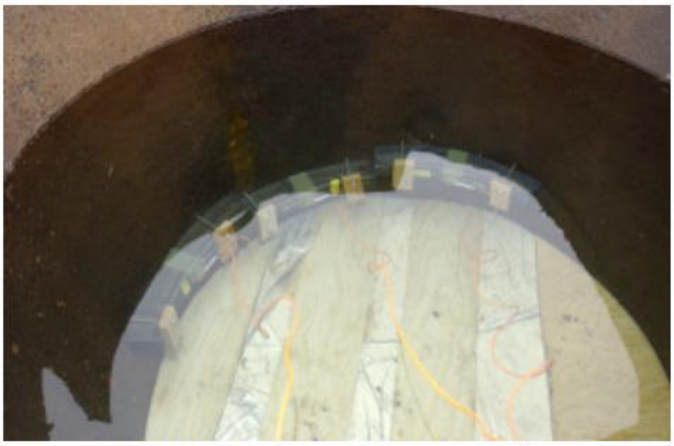
Trial 15 : Comp-B Charges Against Pile Section

- Trial 13 was repeated using Composition-B filled charges.
- The charges have approximately 25 inches of head.



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Trial 15 : Comp-B Charges Against Pile Section

- The charges successfully detonated but penetration was lower than that of the RDX charges.
- No cracking occurred between the cutting planes.

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Trial 15 : Comp-B Charges Against Pile Section

- Perforation did not occur under the initiation systems.
- Perforation did occur after the charge had run-up for two of the three charges.

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Conclusions

- Shaped charge penetration is not significantly effected when saturated sand is used rather than water to back the target.
- Penetration is reduced below the initiation system.
- A detasheet based initiation system proved the most successful. The importance of ensuring contact of the acceptor and donor system with the case was evident from testing.
- Dual initiation increases the penetration in a localized area where the detonation waves interact. This increase comes with the cost of reduced overall penetration as the charge runs-up from two points.
- The RDX charges outperformed the Comp-B charges, perforating the pile and resulting in additional blast related damage.

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WATER DOES FREEZE!

Defence R&D Canada – Suffield ◆ R & D pour la défense Canada – Suffield


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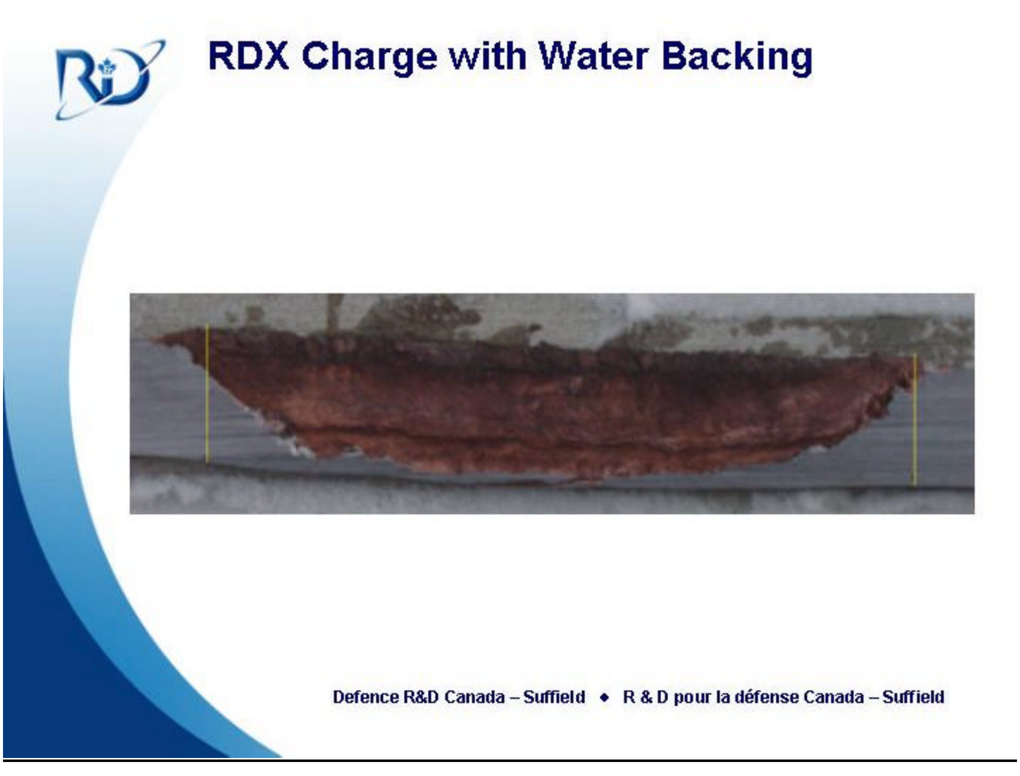
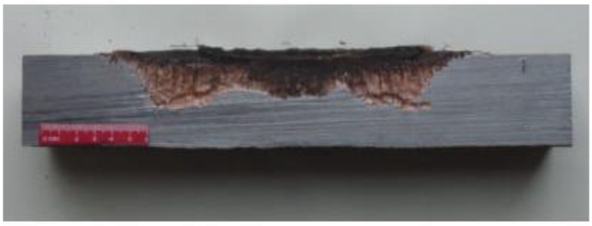

RDX Charge with Water Backing
Defence R&D Canada – Suffield ◆ R & D pour la défense Canada – Suffield


Curved Charge End-to-End
Defence R&D Canada – Suffield • R & D pour la défense Canada – Suffield


Curved Charge End-to-End
Defence R&D Canada – Suffield • R & D pour la défense Canada – Suffield

Initiation of Charge

- Central Initiation



- Three Point Initiation

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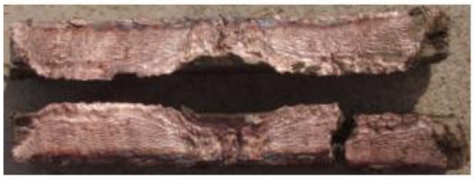
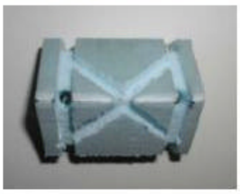
Initiation of Charge

- Six Point Initiation System





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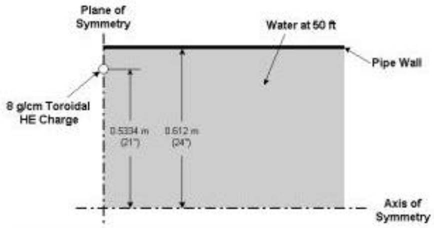
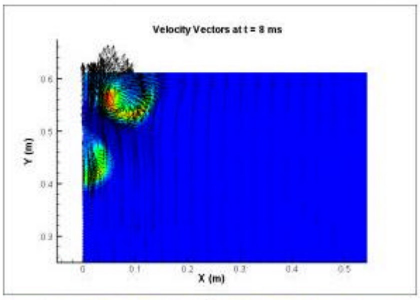
Water Jet

- Toroidal bubble forms but splits during collapse
- Low-speed jet (~20 m/s) evident
- Bubble jet does not appear to apply high pressure loads to pipe wall
- Overall internal pipe pressure high
  - helps maintain solution stability





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Annex D

ESI test range testing report

SNC TEC

SNC TECHNOLOGIES INC.
5, montée des Arsenaux
Le Gardeur (Québec)
Canada J5Z 2P4
Phone: (450) 581-3080
Fax: (450) 581-0275

Copie: 01

Test of Linear Shape Charge at ESI and measurement

Prepared by:
Denis Saint Arnaud, P. Eng.
Technologies Section
Development and Technologies Department

Presented to:
Mr. Jim Lane
MMS

July 2003

MP 19400

TABLE OF CONTENTS

1.0 - INTRODUCTION

These testing were made as part of task 7A of the project. The purpose of this test series is to complete the design and do equipment trials to prepare for final testing in the Gulf of Mexico as part of task 7B.

Testing at ESI was described in test plan 647-004-TEP-DET presented in Annex A. This test plan includes tests to confirm initiation system location and booster design system.

It also included test with the deployment system for 30"ø pile and 48"ø pile. Along with deployment system and severing of the piles, measurement testing should be conducted to get the value of the peak pressure, impulse and energy flux generated.

In addition at least one test was to be done on casings presenting some irregularities (wrinkles).

2.0 - OBSERVATIONS

All the observations were done at ESI range and in a quarry with a submerged area.

Photo # 1 Previous ESI initiation test
Cut complete on half the length

Photo # 2 same set-up as photo # 1
View from the inside

Photo # 3 loading of a LSC
charge set-up for 30"ø pile
Initiation PETN & RDX

Photo # 4 same as photo # 3
View of wooden blocks maintaining
standoff

Photo # 5 same as photo #3
LSC mounted in casing installed
Inside a 30"ø pile

Photo # 6 same as photo # 5
Good cut all along
Left side was initiated with PETN
Right side was initiated with RDX

Photo # 7 same as photo # 5
View of the cut outside in front

Photo # 8 same as photo # 5
View of the cut from the inside

Photo # 9 same as photo # 8
Too powerful LSC caused
deformation

Photo # 10 Loading of an LSC
LSC for 48"ø pile
Initiation PETN & RDX

Photo # 11 same as photo # 10
LSC & casing mount in 48"ø pile

Photo # 12 same as photo # 11
Initiation ready

Photo # 13 48"ø pile cut
Good cut all along
Left side initiated with RDX
Right side initiated with PETN

Photo # 14 same as photo # 13
Cut view from the inside

Photo # 15 same as photo # 13
View in front from the inside

Photo # 16 same as photo # 13
Cut from inside appear very regular

Photo # 17 Same as photo # 13
Outside, extreme right dull gray cut

Photo # 18 'wiper' #7 b (6.3X)
Under PETN initiation fractured cut

Photo # 19 Scorpion assembly with
Four LSC mounted in casing for a
30"ø pile

Photo # 20 Scorpion for a 48"ø pile

Photo # 21 Scorpion for a 30"ø pile
With initiation system on all casings

Photo # 22 Scorpion for a 30"ø pile
System not expanded put in position

Photo # 23 Scorpion for a 30"ø pile
System in position and expanded

Photo # 24 Sensors array identification

Photo # 25 Part of acquisition system

Photo # 26 Analyzer for data
Acquisition system

Photo # 27 Unsuccessful try to Put
30"ø pile in place underwater

Photo # 28 Successful try to put
48"ø pile in place underwater

Photo # 29 48"ø pile partly cut

Photo # 30 48"ø pile partly cut
Both cut doesn’t met
Upper cut deviate away

Photo # 31 48"ø pile partly cut
Two others cut which doesn’t met

Photo # 32 48"ø pile partly cut
Severing between two cut

Photo # 33 48"ø pile partly cut
Severing between two cuts
Transverse fracturing

Photo # 34 48"ø pile partly cut
Transverse fracturing front view

Photo # 35 Successful try to put
30"ø pile in place underwater

Photo # 36 Successful cut on 30"ø pile

Photo # 37 Successful cut on 30"ø pile
Pile severed in two section

Photo # 38 Front view of severed
30"ø pile

Photo # 39 Internal view of severed 30"ø pile, clear-cut observed

Photo # 40 Top view of severed 30"ø pile. Difference can be seen Between top & bottom cut.

Photo # 41 Square cut as top of Photo # 40

Photo # 42 Overlap cut as bottom of Photo # 40

Photo # 43 Part of severed 30"ø pile One fractured point

Photo # 44 Part of severed 30"ø pile Appearance of spalling of the wall

Photo # 45 new casings for 30"ø pile
Wrinkles are visible on internal wall
The non-aligned one was put on test

Photo # 46 Loading of LSC for
30"ø pile with Boosters of RDX
at left foam standoff, at right wood

Photo # 47 Casing & LSC for 30"ø pile
Assembled with foam & wood standoff

Photo # 48 Load casing for 30"ø pile
Initiator installed

Photo # 49 Inside 30"ø pile
LSC mounted in casing

Photo # 50 30"ø pile severed
severing weaken at wood standoff
Wood standoff at right

Photo # 51 Interior of 30"ø pile severed
No difference on all the cut

Photo # 52 Lafitte's Blacksmith Shop
941 Bourbon (1772) N O LA

Photo # 53 Blast of 48"ø pile
Mass of water displaced

3.0 - CONSTRUCTION OF THE CHARGES

Loading of the charges was done using a procedure based on the previous experiments at DRDC Suffield.

- First the LSC was placed aside of the casing to correctly localize the booster holders.
- Next the booster holders were put on the LSC and loaded. In all cases a thin deta sheet (0.125") was put first. Then the two corners on the side were filled either with deta sheet packed or with three det cord made of PETN (50gr 1½"long).
- Two layers of deta sheet (0.125").
- These two booster holders were strongly attached to the LSC with electrical tape.

The two loaded boosters holders being loaded and attached to the LSC, the explosive charge was put inside the casing.
Once inside the casing, at the two extremities the standoff blocks were inserted between the LSC and the casing.
Instant Gasket was then applied at both extremities and the covers plates immediately screwed on the extremities.
Just prior to detonating the charge for severing the piles or other tests, the initiators were installed over the casings.

- First one deta sheet (0.333") was put on the two-machined recess on the casing.
- One initiator was then placed on each of these deta sheets.
- Two slice of deta sheet (0.125") were then placed over the initiator.

4.0 - EXECUTION OF THE TESTS

Test # 1 was done with a LSC curved for a 30"ø pile. The LSC was mounted in a casing. There was two initiators for the charge These were 2½" each side of centerline. One booster was loaded with PETN and RDX was used for the other. This test is presented in pictures 3 to 9.

It resulted in a very good cut, for both the PETN and the RDX.

Test # 2 was done with a LSC curved for a 48"ø pile. The LSC was mounted in a casing. There was two initiators for the charge which were 2½" each side of centerline. The booster were loaded with PETN for one and RDX for the other. This test is covered with photo 10 to 18.

It resulted in very good cut. However under PETN booster it showed a short fracture (~2 inch long).

The two precedent tests bring us to select RDX to fill the booster for the others tests.

Test # 3 was performed with a LSC curved for a 30"ø pile. Four LSC were mounted in four casings. There was two initiators for each charge which were 2½" each side of centerline. The boosters were loaded with RDX for both. All of these charges and casings were assembled on a Scorpion used for their deployment. The deployment of the Scorpion was made inside a 30"ø pile.
Then the pile was driven in a gravel pit submerged by water. After many unsuccessful essay to set the pile, the Scorpion slipped to the bottom of the pile underwater.
After the recuperation of the Scorpion, all the charges and casing were verified, unloaded from the Scorpion and further reloaded. The Scorpion with all the casing was then redeployed inside the 30"ø pile.

Then the pile was reinstalled vertically in the gravel pit submerged by water, at this moment the pile stayed still. This test is illustrated in figures 19, 21-23, 27, 35-44.

It resulted in a very good cut; the pile was severed on a complete circumference and split in two separate parts.

Test # 4 was done with a LSC curved for a 48"ø pile. Four LSC were mounted in four casings. There was two initiators for each charge which were 2½" each side of centerline. Both boosters were loaded with RDX. All of these charges and casings were assembled on a Scorpion which was used for their deployment inside a 48"ø pile.
The driving up of this pile was done between the first unsuccessful planting of the 30"ø pile and reloading of the charges for second successful test for 30"ø pile. The 48"ø pile was set in the gravel pit submerged by water. After some unsuccessful essay to drive the pile in the bottom mud, it rested in the bottom of the 'lake' and the test was done. This test is shown in figures 28-34 and 53.

It resulted in an incomplete cut. Three quarter of the circumference was completely severed. The cuts were incomplete under two LSC and junctions of two cuts were also incomplete.

Test # 5 was on a LSC curved for a 30"ø pile. The LSC was mounted in a casing presenting wrinkles on the wall with the initiators. There was two initiators for the charge, which were 2½" each side of centerline. The boosters were loaded with RDX for both of them. The standoff was set precisely and securely with a ¾" thick wood piece at one extremity and by expanded foam at the other extremity. This test is presented in pictures 45 to 51.

It resulted in a weaken cut under the wood piece and a partly weaken cut under the foam.

5.0 - ANALYSIS OF THE RESULTS

Test # 1 (one loaded LSC against a 30"ø pile) and # 2 (one loaded LSC against a 48"ø pile) were considered as a demonstration that both arrangements for 30"ø pile and 48"ø pile can do reliable severing. The little fracture observed under the PETN booster of the 48" led us to prefer RDX for the booster.

Test # 3 (four LSC loaded and assembled on a scorpion inside a 30"ø pile), which was done in two sequences, brings us a lot of information. When the Scorpion slipped from the pile to the bottom of the 'lake' it showed us that with repetitive shocks with water and mud present as lubricant, even if the scorpion is deployed, it has great chances to move. When the Scorpion was recovered and the charges inspected, the falling of the standoff blocks showed us that this system is limited on the quantities of shock it can accept. This event was also a supplementary proof that the casing closed with the instant gasket is watertight. None of the opened casing presented any water infiltration. And after being reloaded even with a short curing time, they all performed correctly.

Test # 4 (four LSC loaded and assembled in a Scorpion inside a 48"ø pile) brings us also some additional information but also outstanding questions. As this Scorpion was more securely hanged it didn't slipped, even if the pile was submit to some repetitive shocks. The severing of the pile being incomplete all the charges didn't perform their job optimally. The most likely explanation for this incomplete severing is that in one or two casing the standoff blocks moved. If so it could have caused one or many of the following events. The initiation can have been done from only one point instead of two. The initiation can have been done on one or two point but resulting with no intimate contact between the inside of the casing and the booster material. No initiation at all can have been done from the initiators, the initiation resulting from the

shock wave of the charges aside at one or both extremities. Most of these events would be combining with a lost of the correct standoff distance and probably a cantering of the LSC inside the casing. Another possibility is an uneven thickness of material in front of the LSC. Normally wall of these kind of piles is regular enough, but at the seam location a weld reinforcement of ?" can be met, at this point and with some distance it can cause some water gap between the casing and the pile wall.
What really happened is hard to confirm but for sure some supplementary tests should be done on this type of LSC before the Gulf testing.

Test # 5 (one loaded LSC against a 30"ø pile), the LSC being loaded inside a ?" thick wall casing presenting wrinkles on the wall where the initiation should be done. This arrangement testing was also done with standoff maintained at one extremity with a wood piece ¾" thick, 4" long and at the other with expanded foam with a wood piece.
It showed us that initiation is performed properly even if there are wrinkles. However it seem that if too thick wood pieces is in obstruction in the jet path which can weaken jet efficiency.

6.0 - CONCLUSION

Initiation and severing of 30"ø pile can be done with efficiency and repeatability using casing 3/16" or ? " thick wall. For this arrangement we are ready to go in the Gulf of Mexico testing (Task 7B).

Initiation and severing of 48"ø pile has still to be improved.

Data acquisition and measurement for peak pressure, impulse and energy flux were accordingly to the expectation of all involved people. There is no remaining question about measurement so this part of the deployment is ready for Gulf experiment. See results in Annex B.

7.0 - RECOMMANDATION

In view of validating 48"ø pile arrangement supplementary testing should be performed before Gulf testing.

- Test with straight LSC with a correct standoff over a 2" thick steel plate. Install the LSC and standoff holding pieces to have no interference between jet and target. Saw the plate, observe the entire cut and verify if there is any wash out. This test could be done with or without use of a casing and water.
- Test with straight LSC with a correct standoff over a 2" thick steel plate. Install the LSC with standoff wood pieces in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. Saw the plate, observe the entire cut and verify if the cut was affected in regard to the first test. This test can be done with or without use of a casing and water.
- Repeat the same test with straight LSC with a correct standoff over a 2" thick steel plate. . Install the LSC with standoff PVC pipes part in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. Saw the plate, observe the entire cut and verify if the cut was affected in regard to the first test. This test can be done with or without use of a casing and water.
- Test with straight LSC with a correct standoff over a 2" thick steel plate. Then add a height to the standoff to simulate the height caused by the variation caused on wall of the pile as where we met seam weld reinforcement. Install the LSC with standoff wood pieces in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. Saw the plate, observe the entire cut and verify if the entire cut was affected. This test can be done with or without use of a casing and water.

With all these results helping to interpret correctly 48" LSC comportment at ESI testing (task 7A). Some additional tests would be valuable on actual LSC.

- Test with one curved LSC (for 48"ø pile) with a correct standoff inside a 48"ø pile. Install the LSC with standoff wood pieces in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. LSC mounted inside casing, do the testing. Saw the section, observe the cut and verify if the cut was affected. This test should be done with use of water.
- Test with one curved LSC (for 48"ø pile) with a correct standoff inside a 48"ø pile. Install the LSC with standoff PVC pipe pieces in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. LSC mounted inside casing, do the testing. Saw the section, observe the cut and verify if the cut was affected. This test can be done with use of water.
- Test with four curved LSC (for 48"ø pile) with a correct standoff inside a 48"ø pile. Install the LSC with standoff choose pieces in interference with the extremities of the LSC (interference at least 1" long each extremities), so it'll have 1" interference between jet and target at each extremities. LSC mounted inside casing, all the casings installed on a scorpion or arranged as if they were mounted on a scorpion, do the testing. Saw the section, observe the cut and verify if the cut was affected. This test can be done with use of water.

With these latter tests giving good results then Gulf testing (task 7B) could be next step.

8.0 - REFERENCES

[1] Fundamental of Shaped Charges, W.P. Walters, J.A. Zukas, John Wiley & Sons inc, ISBN 0-471-62172-2, 1989

9.0 - DISTRIBUTION LIST

Jim Lane MMS
Arvind Shah MMS
T.J. Broussard MMS
Sharon Buffington MMS
Charles E. Smith MMS
Michael Hargrove MMS
William Poe ESI
Robert W. Janda Sonalysts
Duff Kirklewski Sonalysts
Jean Marc Pigeon SNC TEC
Pierre Pelletier SNC TEC
Nathalie Maher SNC TEC

Annex A

Test plan 647-004-TEP-DET

SNC TEC

PLAN D'ESSAI / *TEST PLAN*

TITRE DE L'ESSAI / *TEST TITLE*:	**Test of linear shape charge on piles, project MMS**		
Demandeur / *Requested by:*	Denis Saint Arnaud	**No. de l'essai /** *Test number:*	647-004-TEP-DET
Endroit de l'essai / *Test location:*	ESI Clinton LA	Révision / Revision:	0
Date émise / *Date submitted:*	July 2003	**Projet, Produit /** *Project, Product:*	MMS
Date requise / *Date required:*	July 2003	**No. Work Order /** *Work Order No.:*	MP19400

Présence du demandeur ou délégué/ Required presence of authorized person:	☒ OuI, NOM / Yes, NAME		☐ NON REQUIS / No

RUBRIQUES OBLIGATOIRES / *MANDATORY INFORMATION:*

1. **BUT /** *AIM:*

The first aim of these tests is to confirm that LSC mounted in appropriate casings will entirely severe 30 & 48"ø piles.

The second aim is to confirm that we can properly get data and do measurement accordingly to parameters agreed with MMS.

2. **PROCÉDURES À SUIVRE /** *TEST PROCEDURE*:

Mount the linear shape charge with booster holders filled inside the casings set-up ensuring correct stand-off.

Close the casing and make them watertight

Assemble initiation system over the casing.

Evacuate area, connect initiation system and do the test.

Evaluate penetration depth, shape or sectioning capability.

3. **MESURES DE SÉCURITÉ PARTICULIÈRES /** *SPECIFIC SECURITY MEASURES:*

a) Mesures de sécurité particulières

1.1D explosive manipulation. Use of appropriate protection shield and distance.
Following testing agency safety procedure.

b) Analyse de risques spécifique à l'essai

☐ **NON APPLICABLE /** *NOT APPLICABLE*
☒ **CONFORME À L'ANALYSE DE RISQUES DÉTAILLÉE NO. : /** *MEETS THE RISK ANALYSIS No.*
☐ **NON CONFORME À L'ANALYSE DE RISQUES DÉTAILLÉE NO.: /** *DOES NOT MEET THE RISK ANALYSIS No.*

NOMS DES PARTICIPANTS / *ATTENDEES NAME*

Nom / Département :
Name / Department :

Indiquer les changements/ *Modifications :*

Chef de projet / *Chief of the project* | **Directeur responsable du projet /** *Project Manager*

4. COMPOSANTES CRITIQUES UTILISÉES POUR L'ESSAI SONT CONFORMES / *CRITICAL COMPONENTS USED ARE CONFORM :*

☐ **N/A** ☒ **OUI/***YES* ☐ **NON/***NO*

Si non, donner la raison / *If not give the reason:*

9.1 RUBRIQUES APPLICABLES / *APPLICABLE INFORMATION:*

	A	N/A		A	N/A
Produits à évaluer / Product to test	☒	☐	Armes, Équipement à utiliser / Weapon, Equipment	☒	☐
Charges propulsives / *Propelling charge*	☐	☒	**Critères d'acceptation /** *Acceptance criteria*	☒	☐
Données à recueillir / *Measurements*	☒	☐	**Autres rubriques /** *Other information*	☐	☒
Dessins applicables / *Applicable drawings*	☒	☐	**Références /** *References*	☒	☐

Product to test

Table #1: Linear shape charge for 30"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
1	RDX	Curved charge ~21" long	Curved for 30"ø pile	1.25 inches	Pile section 30"ø Nonel initiator	One

Table #2: Linear shape charge for 48"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
2	RDX	Curved charge ~34" long	Curved for 48"ø pile	1.25 inches	Pile section 48"ø Nonel initiator	One

Table #3: Four linear shape charge for 30"ø pile enclosed in casing, all of them mounted on a scorpion, all the assembly put inside a pile and essay underwater. To validate efficiency of the entire system.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
3	RDX	Curved charge ~21" long	Curved for 30"ø pile	1.25 inches	Pile section Nonel initiator	Four deployed by a scorpion

Table #4: Four linear shape charge for 48"ø pile enclosed in casings, all of them mounted on a Scorpion, all the assembly put inside a pile and essay underwater. To validate efficiency of the entire system.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
4	RDX	Curved charge ~34" long	Curved for 30"ø pile	1.25 inches	Pile section Nonel initiator	Four deployed by a scorpion

Table #5: Linear shape charge for 30"ø pile enclosed in casing to confirm that initiation is effective through a casing with wrinkles on the wall.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
5	RDX	Curved charge ~21" long	Curved for 30"ø pile, ? " thick HSS	1.25 inches	Pile section 30"ø Nonel initiator	One

Table #6 : Results

Test #	Explosive	Number of charges	Casing damages	Target damages	Photo
1	RDX	1			
2	RDX	1			
3	RDX	4			
4	RDX	4			
5	RDX	1			

Equipment

Per test # 1 : 30"ø pile
Linear shape charge filled with RDX & casing curved for the pile
Booster system
Initiation system

Per test #2 : 48"ø pile
Linear shape charge filled with RDX & casing curved for the pile
Booster system

Initiation system

Per test # 3 : 30"ø pile
Four linear shape charge filled with RDX & casing curved for the pile
Booster system
Scorpion system
Initiation system
Sufficient depth of water to submerge the pile

Per test # 4 : 48"ø pile
Four linear shape charge filled with RDX & casing curved for the pile
Booster system
Scorpion system
Initiation system
Sufficient depth of water to submerge the pile

Per test # 5 : 30"ø pile
Linear shape charge filled with RDX & casing curved for the pile
Booster system
Initiation system

Acceptance criteria

Test is considered successful if target is entirely cut.

<u>Measurements</u>

After each tests remaining casing and target must be photographed to evaluate damages.
Targets must be cut perpendicularly to jet propagation.
Depth and shape of penetration must be evaluated and photographed.

Annex B

Sonalysts report dry run

This report which was part of ESI test Range report has been entirely reproduced as the next Annex E

Annex E

ESI test range testing – Sonalysts test report

BLASTING MEASUREMENT

Preliminary Testing at Bunch Quarry, Clinton LA
9 July 2003

PREPARED FOR:

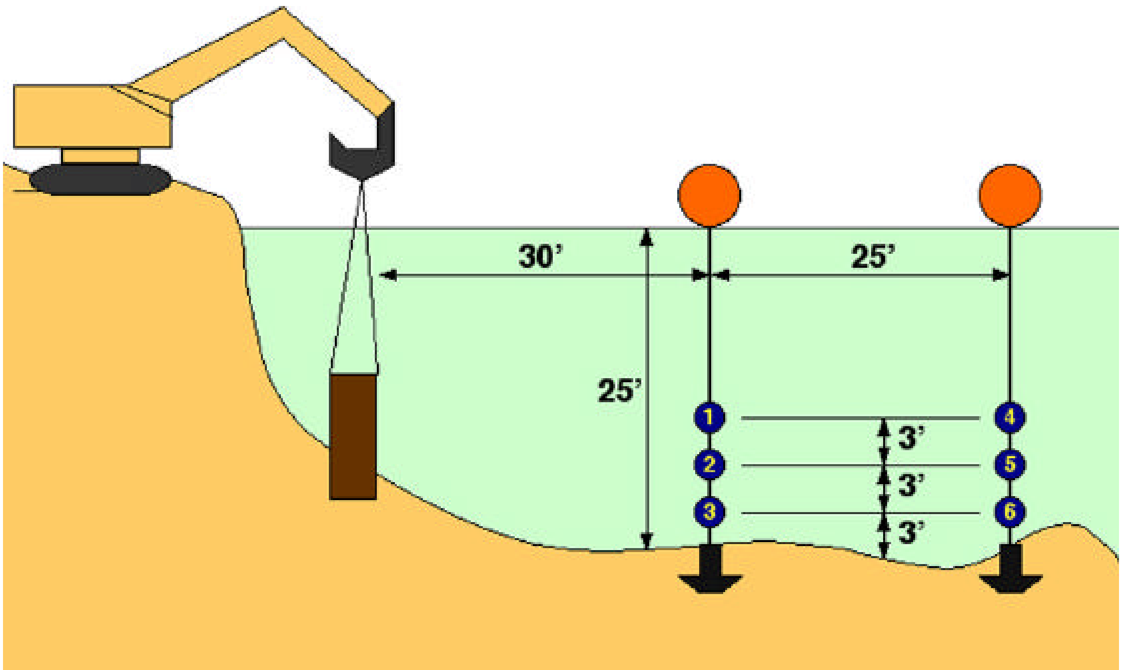
SNC TECHNOLOGIES, IN C.
5, MONTEE DES ARSENA UX
LE GARDEUR, QC CANA DA
J5Z 2P4

PREPARED BY:

SONALYSTS, INC.
215 PARKWAY NORTH
WATERFORD, CT 06385

GULF BLAST MEASUREME NT

Preliminary Testing at Bunch Quarry, Clinton LA
9 July 2003



1.0 - BLAST TRANSDUCER SETUP FOR SHAPED CHARGE EXPERIMENTS

1.1 Comments

- In general, transducers produced shock wave peak pressures in the order of magnitude of 240 psi at 30' and 180 psi at 55' for 30" pipe, and 210 psi at 30' and 130 psi at 55' for the 48" pipe.

- Use of Connor's developed similitude equations for 30" pipe with charge weight of 4.58 lb yields 215 psi at 30' and 64 psi at 55'. Numbers for 48" pipe with charge weight of 6.86 lb are 282 psi at 30' and 84 psi at 55'.

- Multiple peaks (<0.5 msec) seen in a given transducer time trace are probably due to reflections in pipe structure or charge delays. Larger delays (> 1 msec) may be bottom or quarry wall reflections.

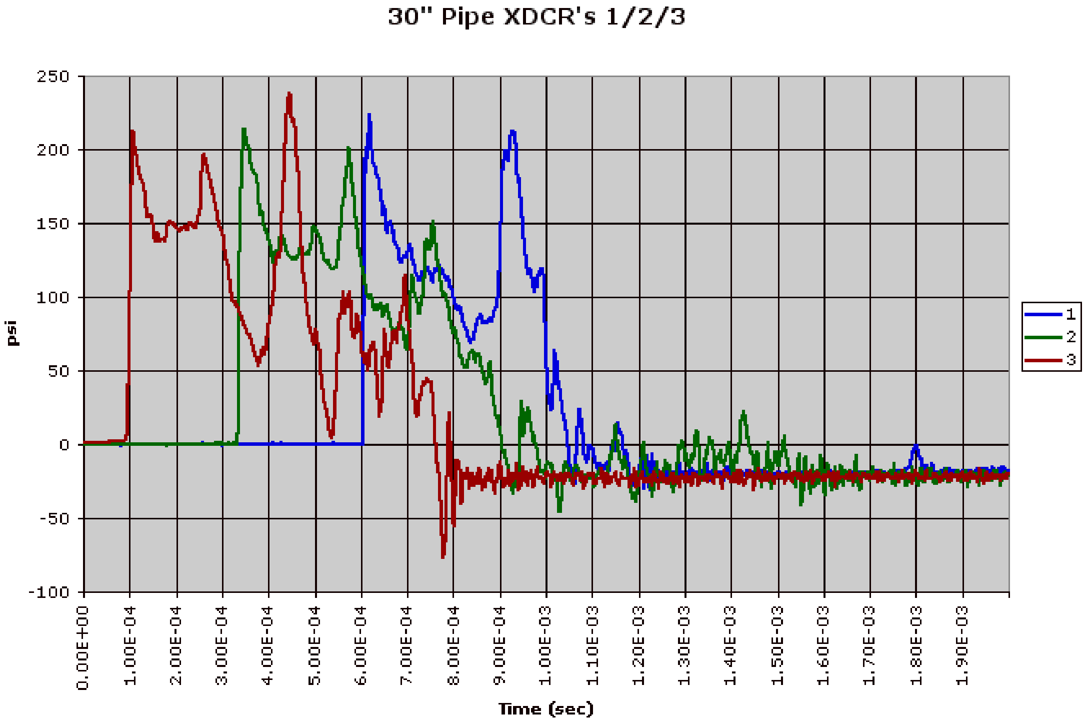
- The 48" charges did not set off correctly and results are not what would be expected for correct charge detonation.

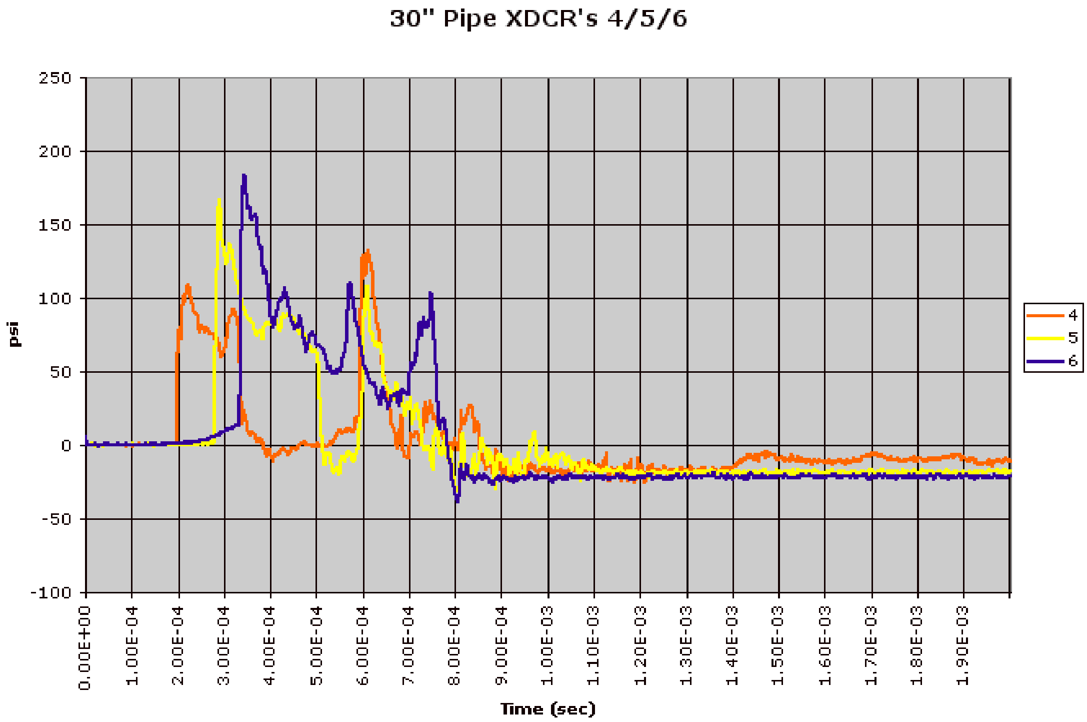
- Pipes and charges were not placed below mudline hence resulting pressures are higher than would be expected for below mudline placement.

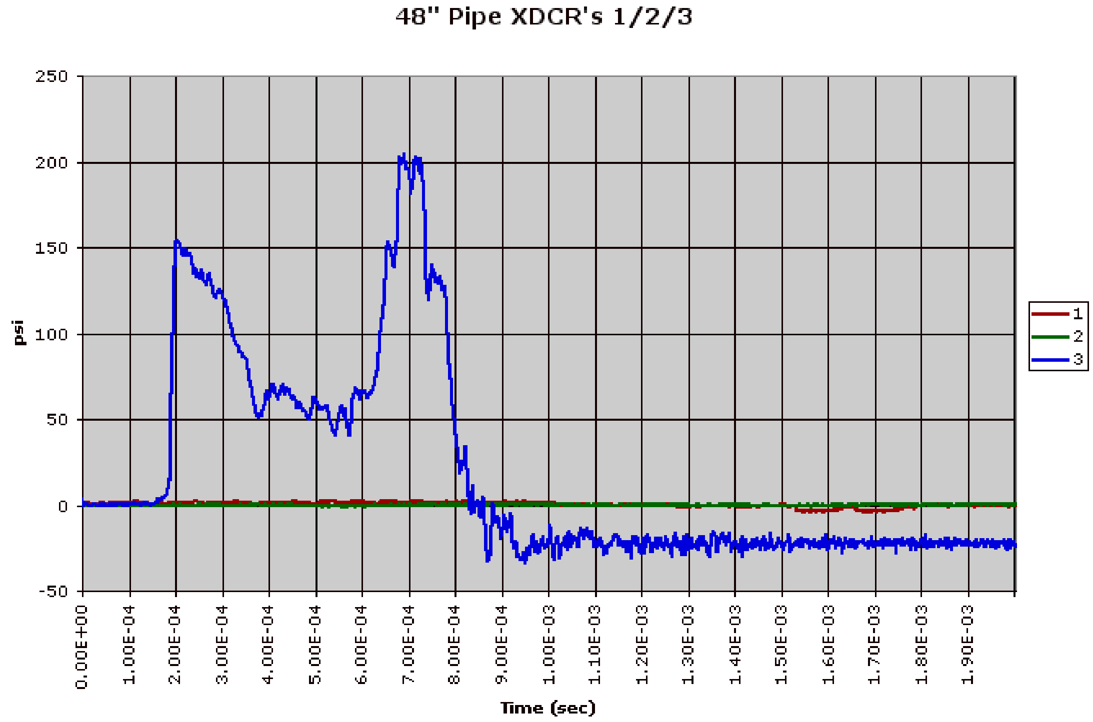
- 48" pipe test was run first. Transducers 1 and 2 did not respond. Cables were checked and re-installed and equipment reset. For 30" pipe test, all channels yielded valid data.

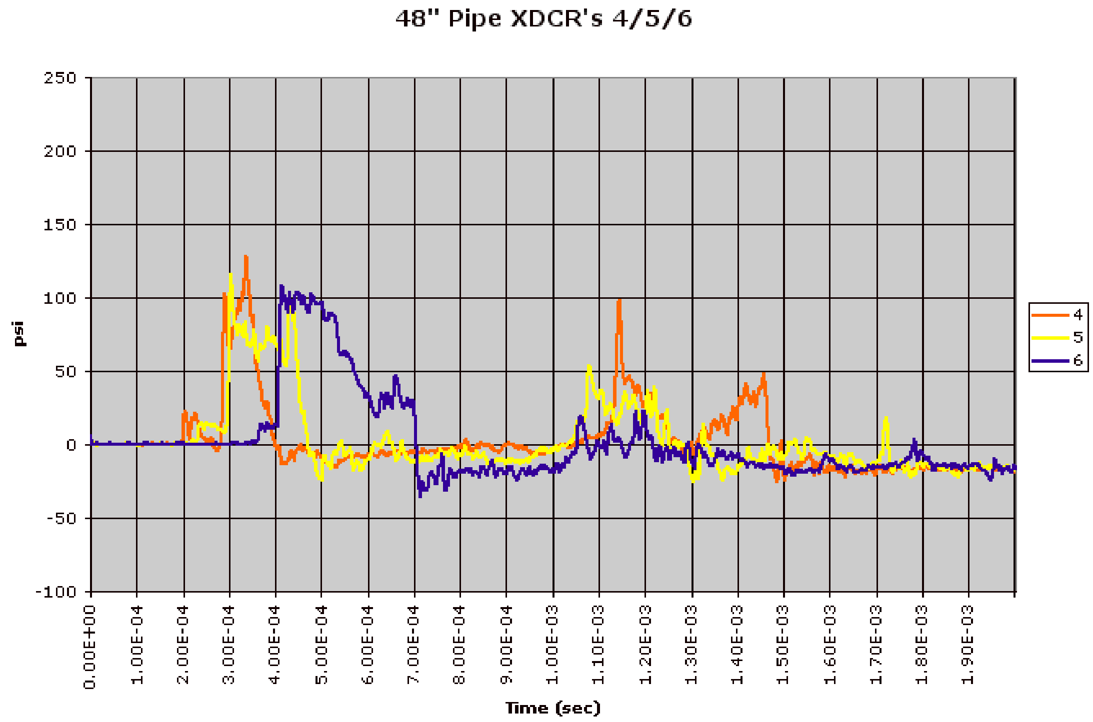
- Propagation loss will be different in the quarry setting compared with open water due to close in reflections of shock pulse energy and solid restriction behind pipe (quarry wall). This should explain the low rate of pressure fall-off with increased distance.

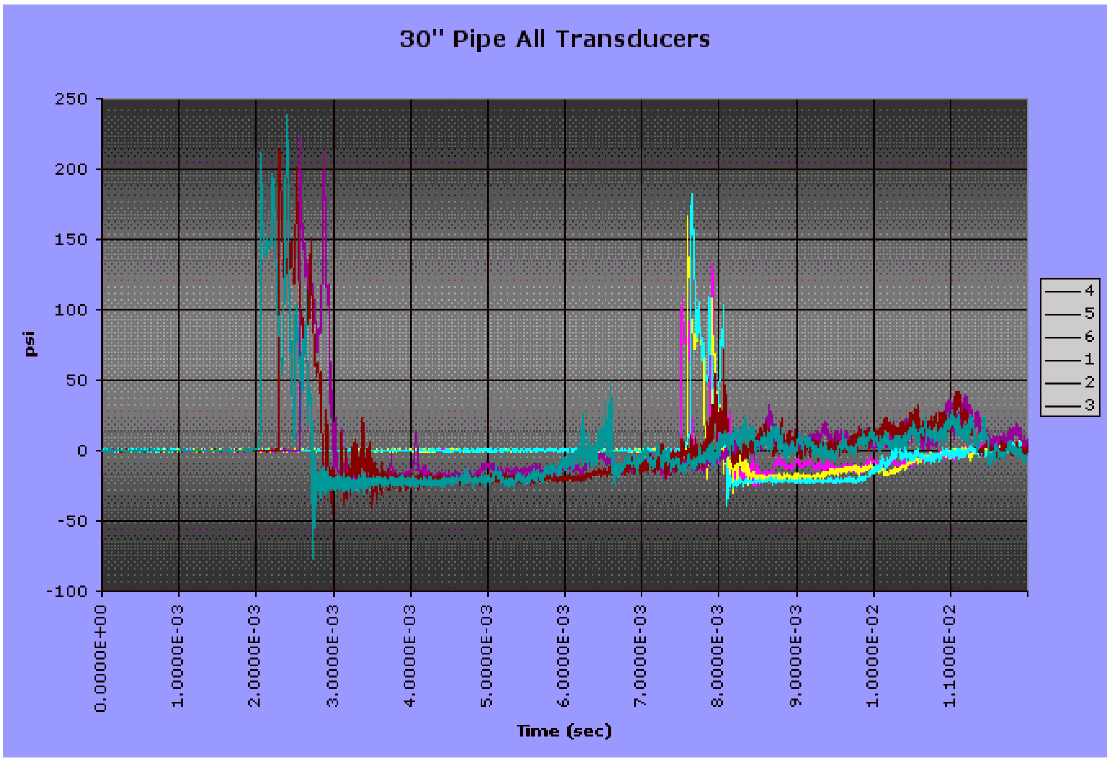
- Graphs of transducer shock pulse data follow.

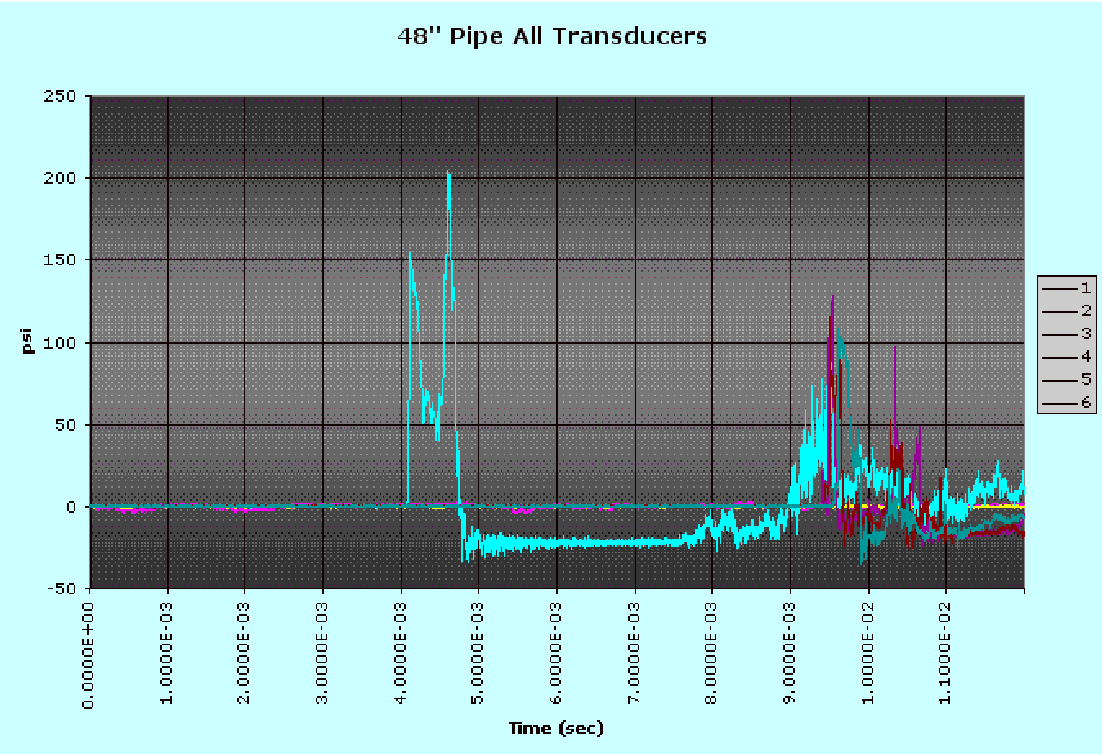

30" Pipe XDCR's 1/2/3
psi
250
200
150
100
50
0
-50
-100
0.00E+00
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
6.00E-04
7.00E-04
8.00E-04
9.00E-04
1.00E-03
1.10E-03
1.20E-03
1.30E-03
1.40E-03
1.50E-03
1.60E-03
1.70E-03
1.80E-03
1.90E-03
Time (sec)
1
2
3


30" Pipe XDCR's 4/5/6
psi
250
200
150
100
50
0
-50
-100
0.00E+00
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
6.00E-04
7.00E-04
8.00E-04
9.00E-04
1.00E-03
1.10E-03
1.20E-03
1.30E-03
1.40E-03
1.50E-03
1.60E-03
1.70E-03
1.80E-03
1.90E-03
Time (sec)
4
5
6


48" Pipe XDCR's 1/2/3
psi
250
200
150
100
50
0
-50
0.00E+00
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
6.00E-04
7.00E-04
8.00E-04
9.00E-04
1.00E-03
1.10E-03
1.20E-03
1.30E-03
1.40E-03
1.50E-03
1.60E-03
1.70E-03
1.80E-03
1.90E-03
Time (sec)
1
2
3

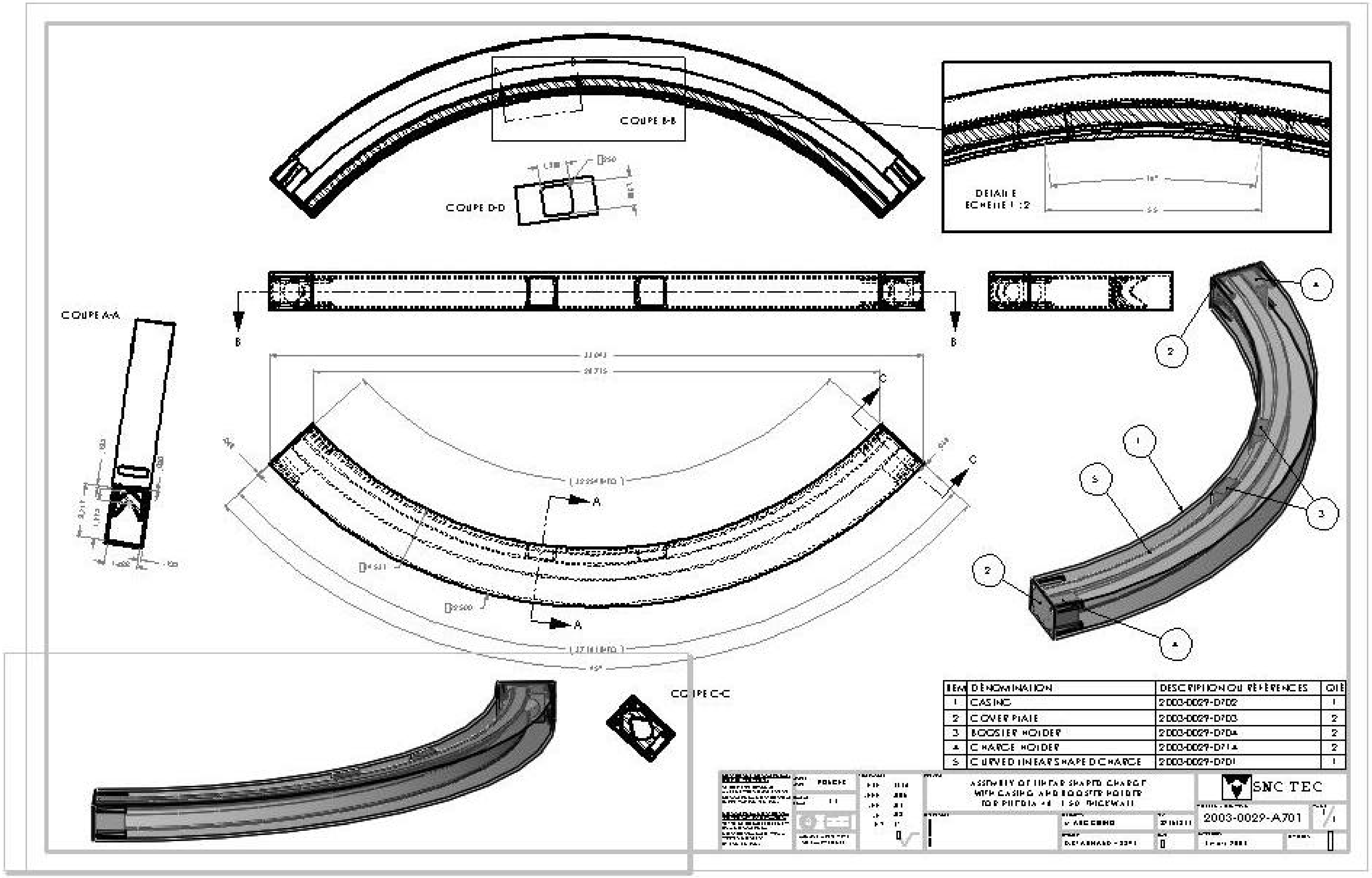

48" Pipe XDCR's 4/5/6
psi
250
200
150
100
50
0
-50
-100
0.00E+00
1.00E-04
2.00E-04
3.00E-04
4.00E-04
5.00E-04
6.00E-04
7.00E-04
8.00E-04
9.00E-04
1.00E-03
1.10E-03
1.20E-03
1.30E-03
1.40E-03
1.50E-03
1.60E-03
1.70E-03
1.80E-03
1.90E-03
Time (sec)
4
5
6


30" Pipe All Transducers
psi
250
200
150
100
50
0
-50
-100
0.0000E+00
1.0000E-03
2.0000E-03
3.0000E-03
4.0000E-03
5.0000E-03
6.0000E-03
7.0000E-03
8.0000E-03
9.0000E-03
1.0000E-02
1.1000E-02
Time (sec)
4
5
6
1
2
3


48" Pipe All Transducers
psi
250
200
150
100
50
0
-50
0.0000E+00
1.0000E-03
2.0000E-03
3.0000E-03
4.0000E-03
5.0000E-03
6.0000E-03
7.0000E-03
8.0000E-03
9.0000E-03
1.0000E-02
1.1000E-02
Time (sec)
1
2
3
4
5
6

Annex F

Engineered charge parts drawings


COUPE B-B
COUPE D-D
DETAIL E
ECHELLE 1:2
COUPE A-A
COUPE C-C
ITEM
DENOMINATION
DESCRIPTION OU REFERENCES
QTE
1 CASING 2003-0029-D702 1
2 COVER PLATE 2003-0029-D703 2
3 BOOSTER HOLDER 2003-0029-D704 2
4 CHARGE HOLDER 2003-0029-D714 2
5 CURVED LINEAR SHAPED CHARGE 2003-0029-D701 1
SNC TEC
2003-0029-A701

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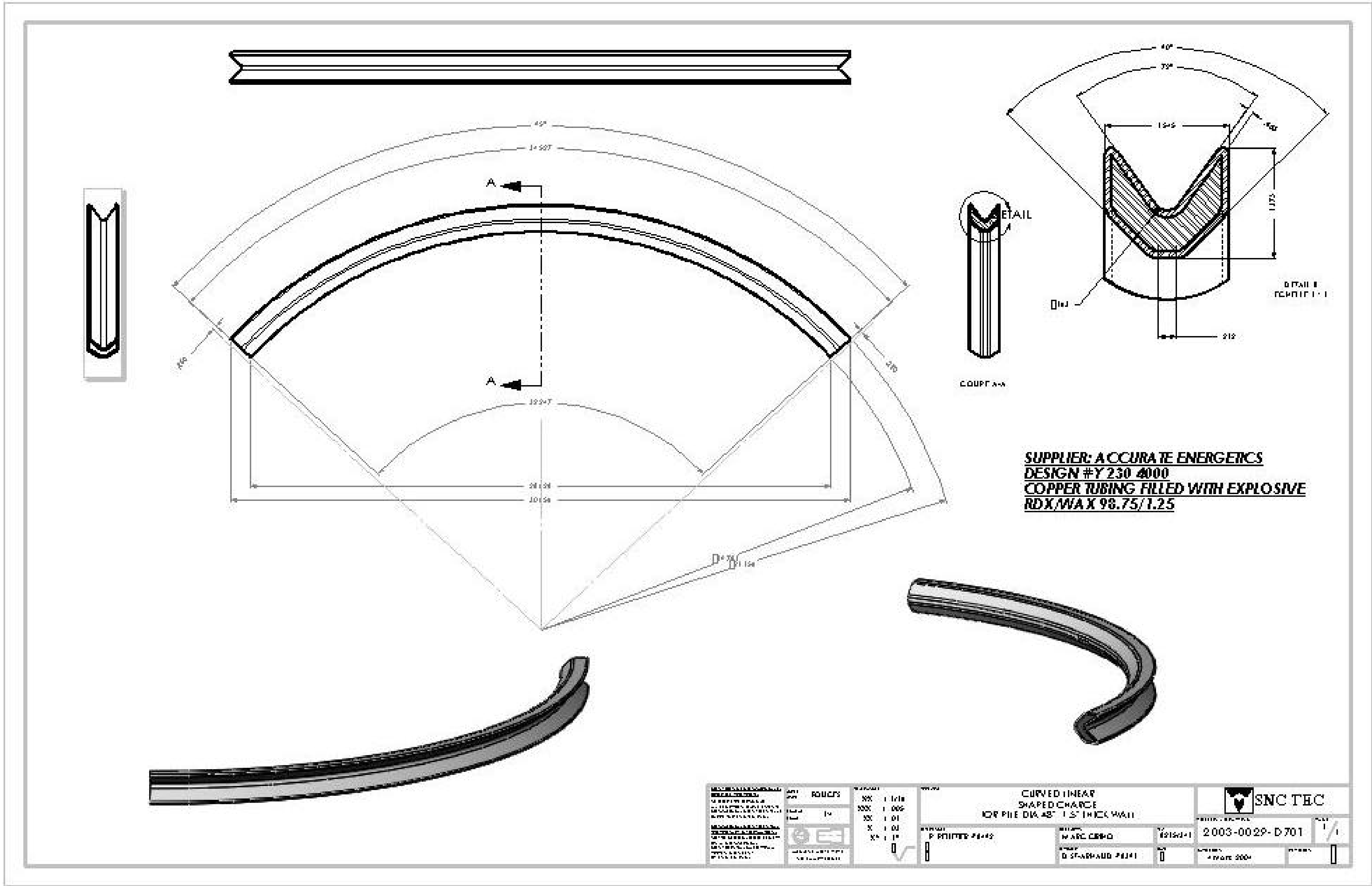
DETAIL
COUPE A-A
SUPPLIER: ACCURATE ENERGETICS
DESIGN #Y 230 4000
COPPER TUBING FILLED WITH EXPLOSIVE
RDX/WAX 98.75/1.25
CURVED LINEAR
SHAPED CHARGE
SNC TEC
2003-0029-D701

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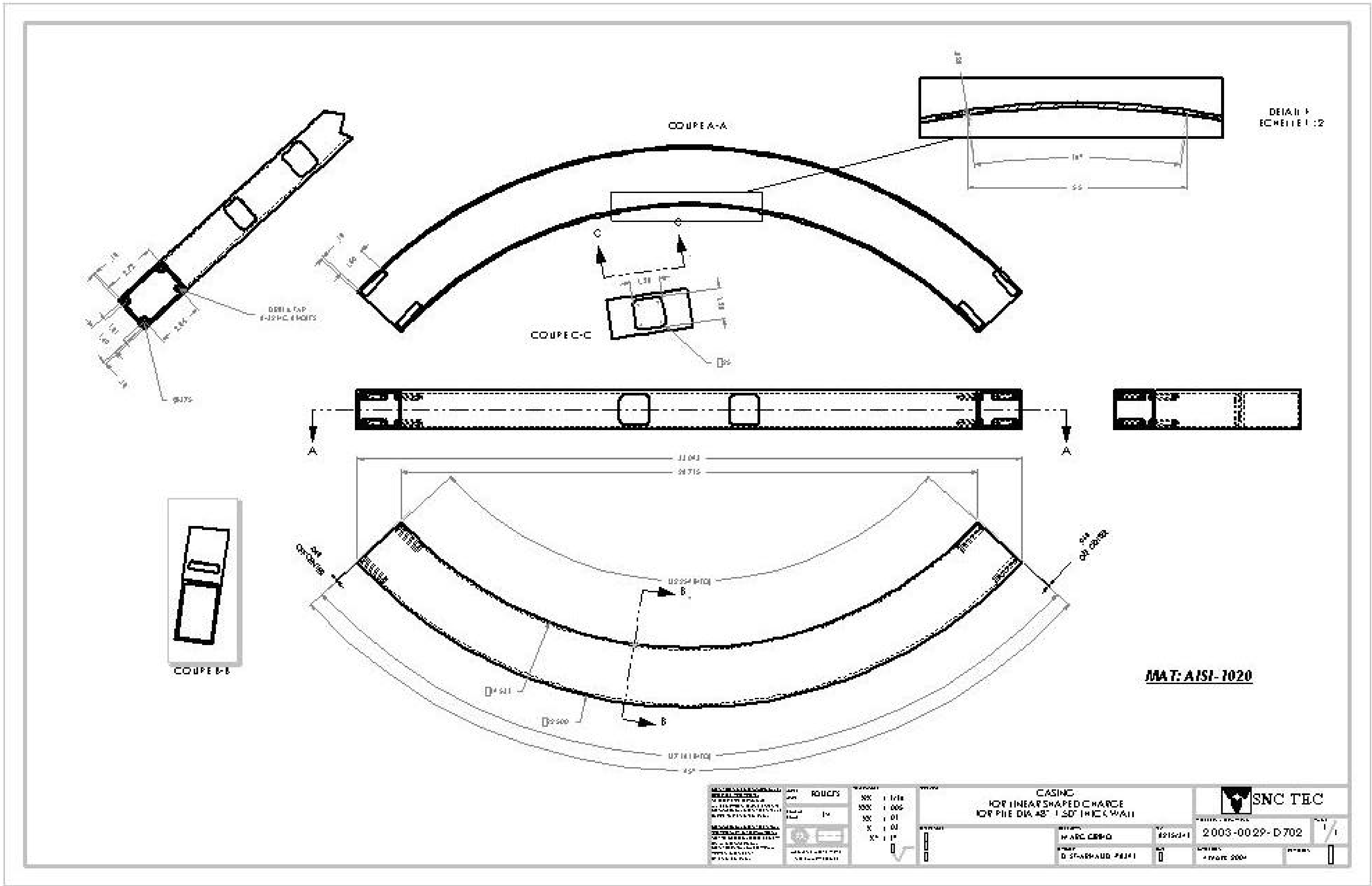
COUPE A-A
DETAIL F
ECHELLE 1:2
COUPE C-C
COUPE B-B
MAT: AISI-1020
CASING
FOR LINEAR SHAPED CHARGE
FOR PILE DIA 48" 1.50" THICK WALL
SNC TEC
2003-0029-D702
MARC GIRARD

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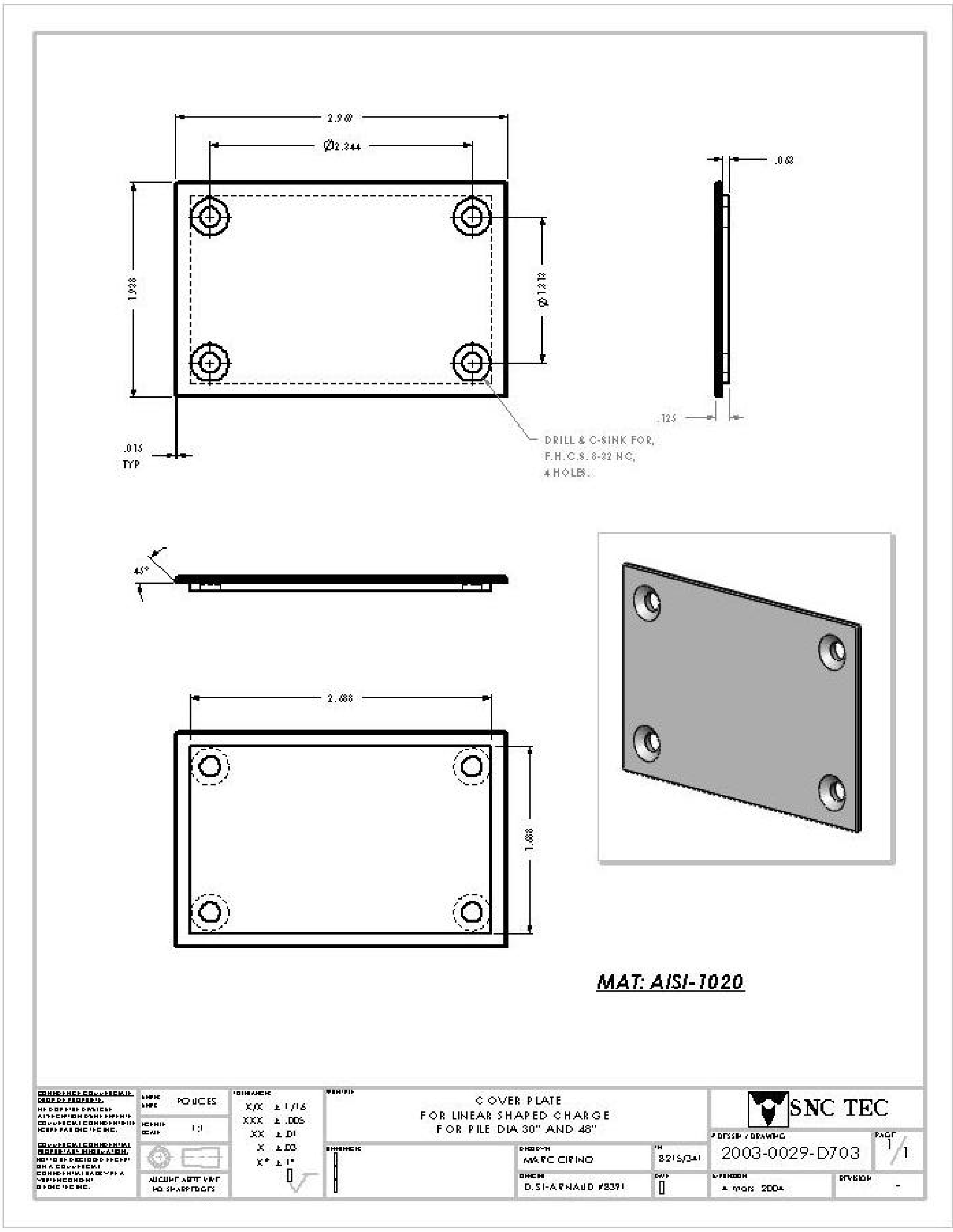
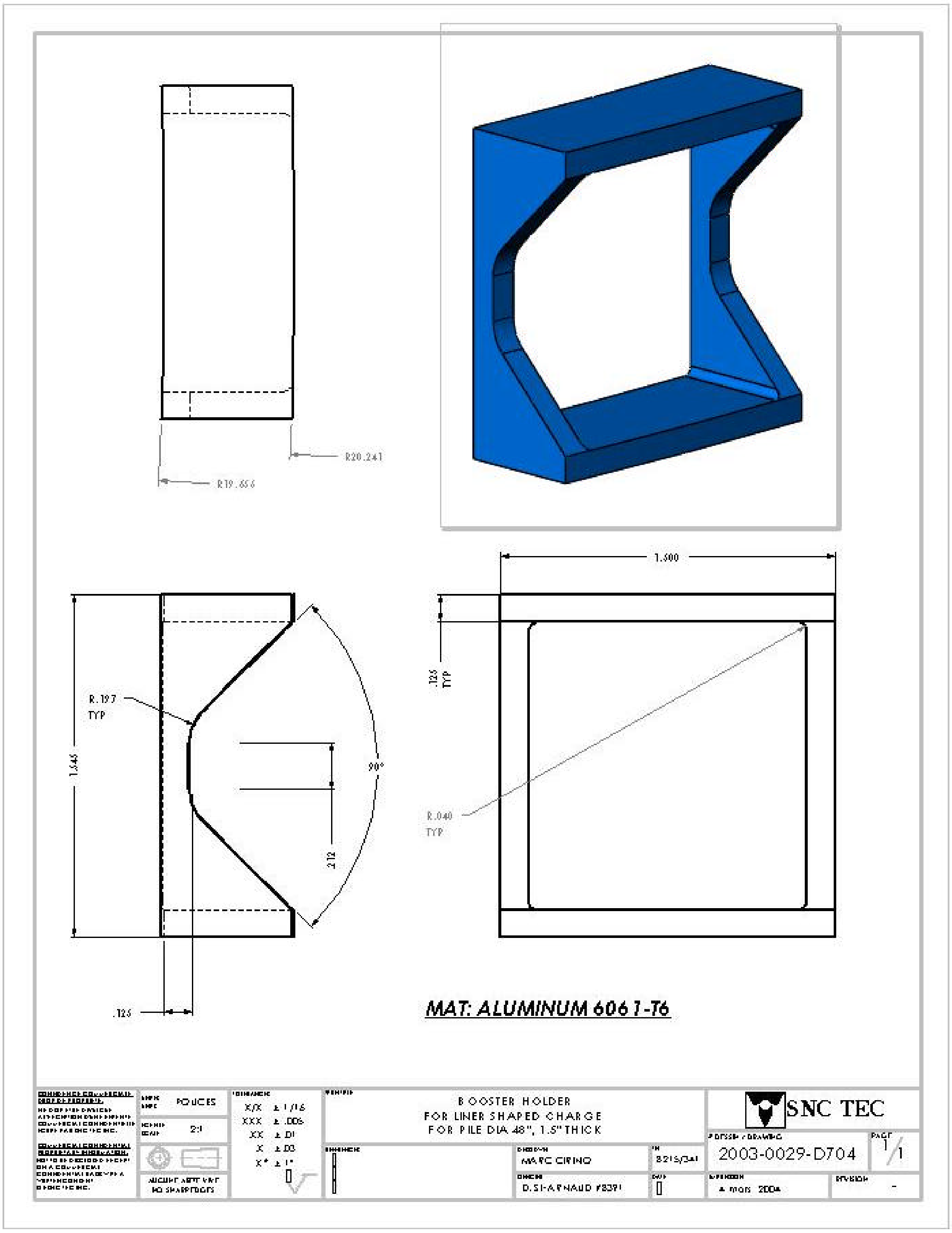
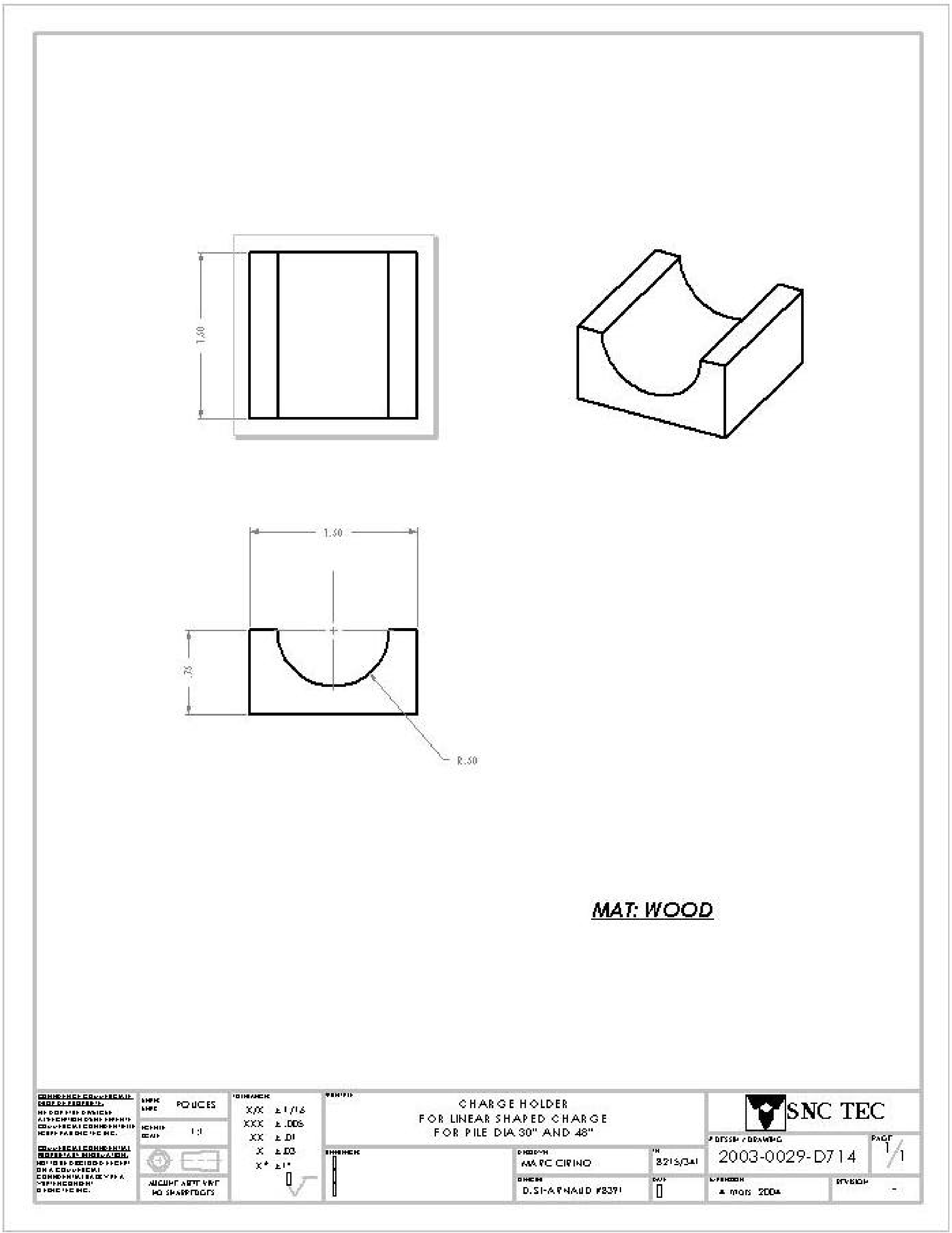

DRILL & C-SINK FOR,
F.H.C.S. 8-32 NC,
4 HOLES.
MAT: AISI-1020
POUCES
COVER PLATE
FOR LINEAR SHAPED CHARGE
FOR PILE DIA 30" AND 48"
SNC TEC
2003-0029-D703
MARC CIRINO


R20.241
R19.656
1.500
.125
TYP
R.197
TYP
1.645
90°
.212
R.040
TYP
.125
MAT: ALUMINUM 6061-T6
POUCES
2:1
X/X ± 1/16
XXX ± .005
XX ± .01
X ± .03
X° ± 1°
BOOSTER HOLDER
FOR LINER SHAPED CHARGE
FOR PILE DIA 48", 1.5" THICK
SNC TEC
2003-0029-D704
1/1
MARC CIRINO
D.ST-ARNAUD


1.50
1.50
R.50
MAT: WOOD
POUCES
CHARGE HOLDER
FOR LINEAR SHAPED CHARGE
FOR PILE DIA 30" AND 48"
SNC TEC
2003-0029-D714
MARC CIRINO

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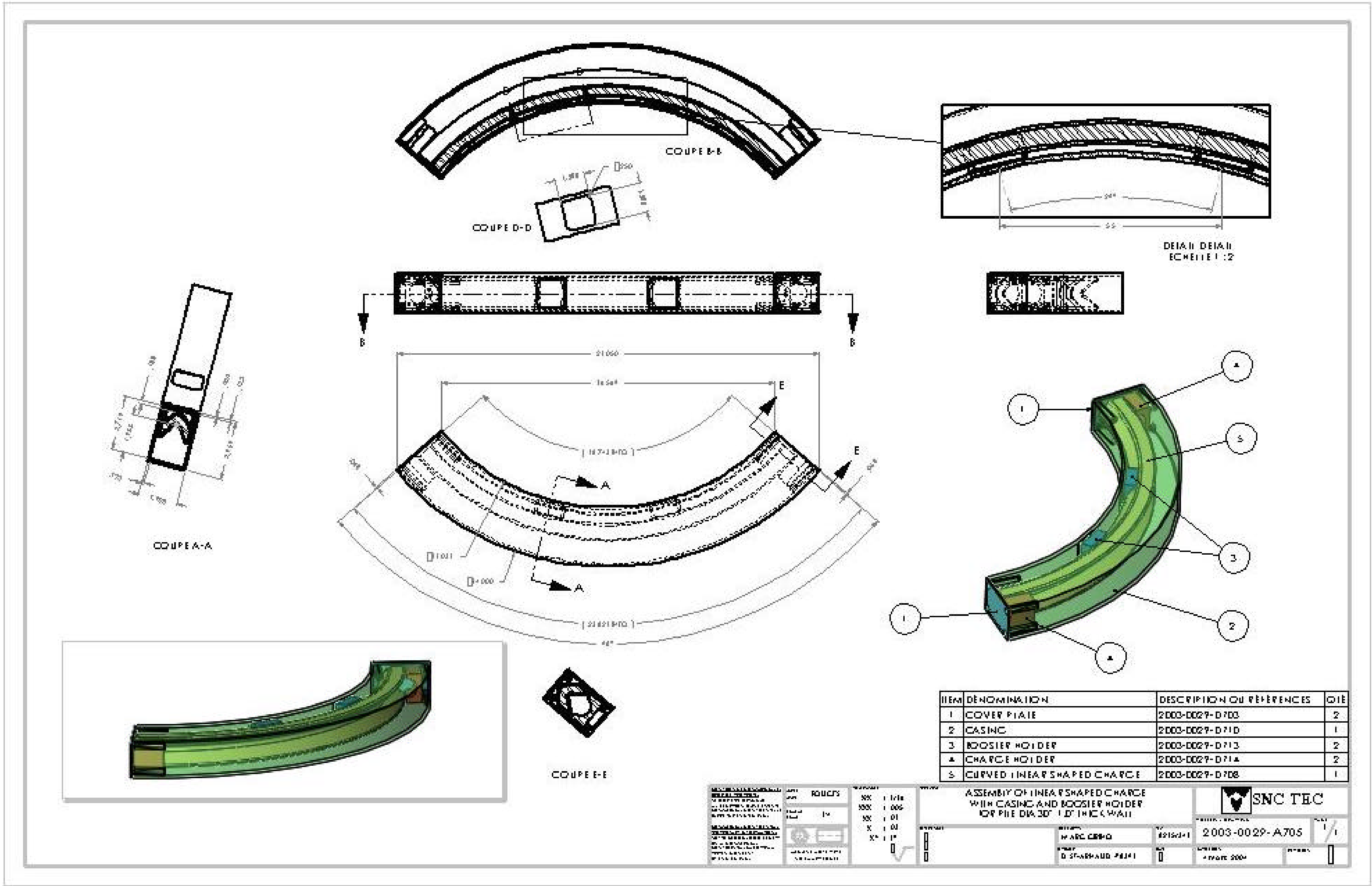
COUPE B-B
COUPE D-D
DETAIL DETAIL
ECHELLE 1:2
B
B
E
E
A
A
COUPE A-A
COUPE E-E
ITEM | DENOMINATION | DESCRIPTION OU REFERENCES | QTE
1 | COVER PLATE | 2003-0029-D703 | 2
2 | CASING | 2003-0029-D710 | 1
3 | BOOSTER HOLDER | 2003-0029-D713 | 2
4 | CHARGE HOLDER | 2003-0029-D714 | 2
5 | CURVED LINEAR SHAPED CHARGE | 2003-0029-D708 | 1
ASSEMBLY OF LINEAR SHAPED CHARGE
WITH CASING AND BOOSTER HOLDER
FOR PILE DIA 30" 1.0" THICK WALL
SNC TEC
2003-0029-A705
1/1

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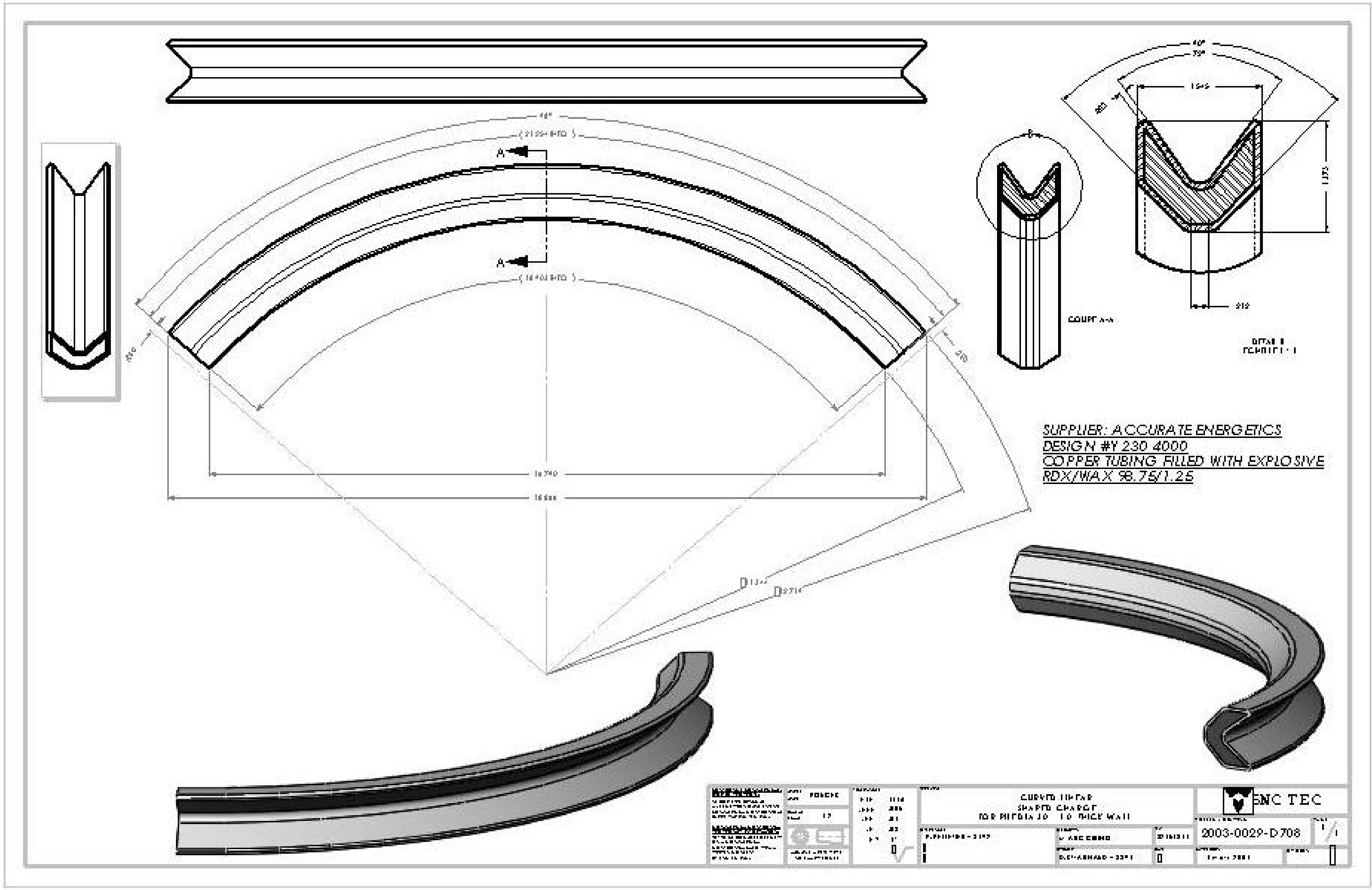
SUPPLIER: ACCURATE ENERGETICS
DESIGN #Y 230 4000
COPPER TUBING FILLED WITH EXPLOSIVE
RDX/WAX 98.75/1.25
ENC TEC
2003-0029-D708

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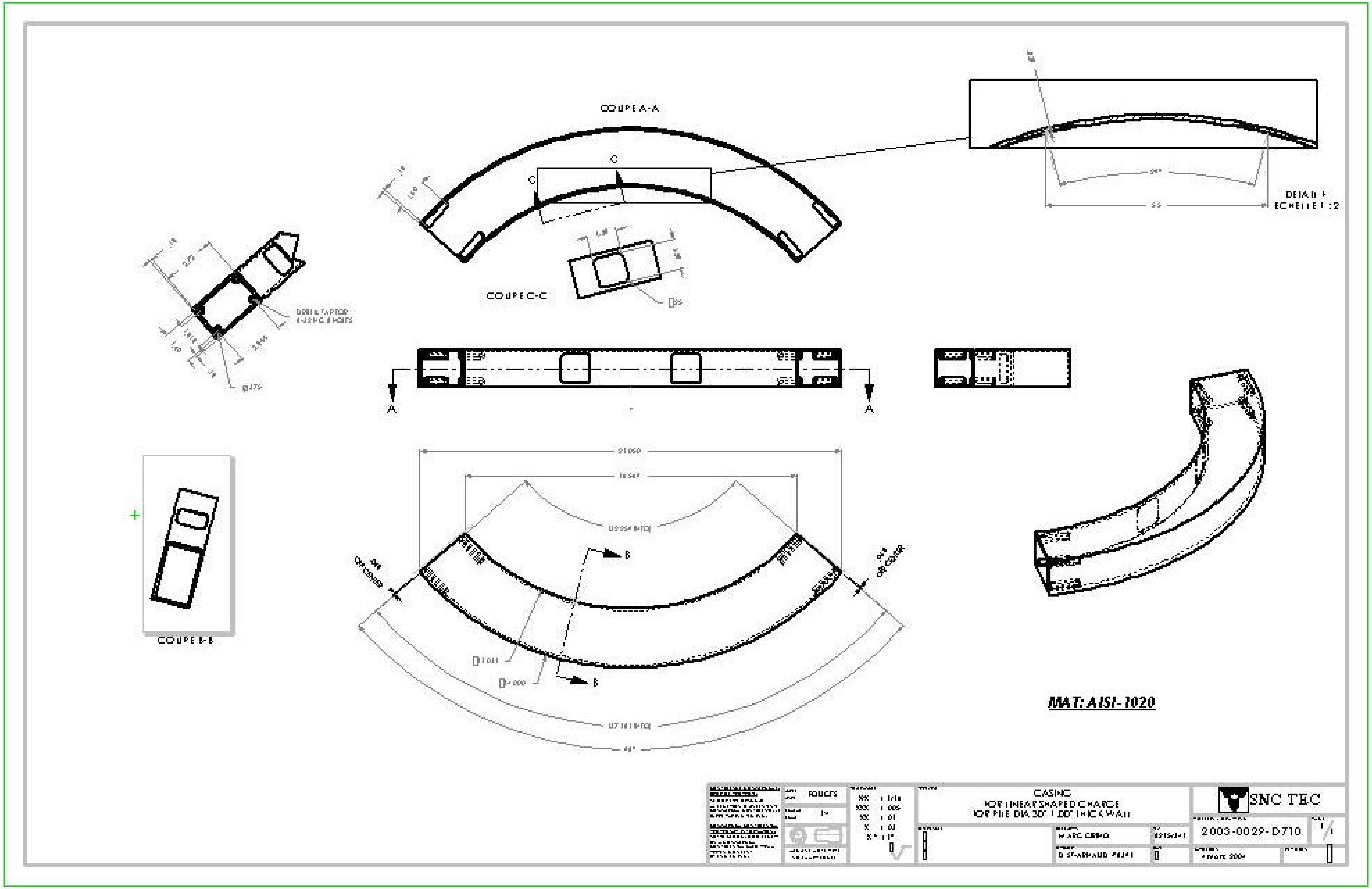
COUPE A-A
COUPE C-C
COUPE B-B
DETAIL F
ECHELLE 1:2
MAT: AISI-1020
CASING
FOR LINEAR SHAPED CHARGE
FOR PILE DIA 30" 1.00" THICK WALL
SNC TEC
2003-0029-D710

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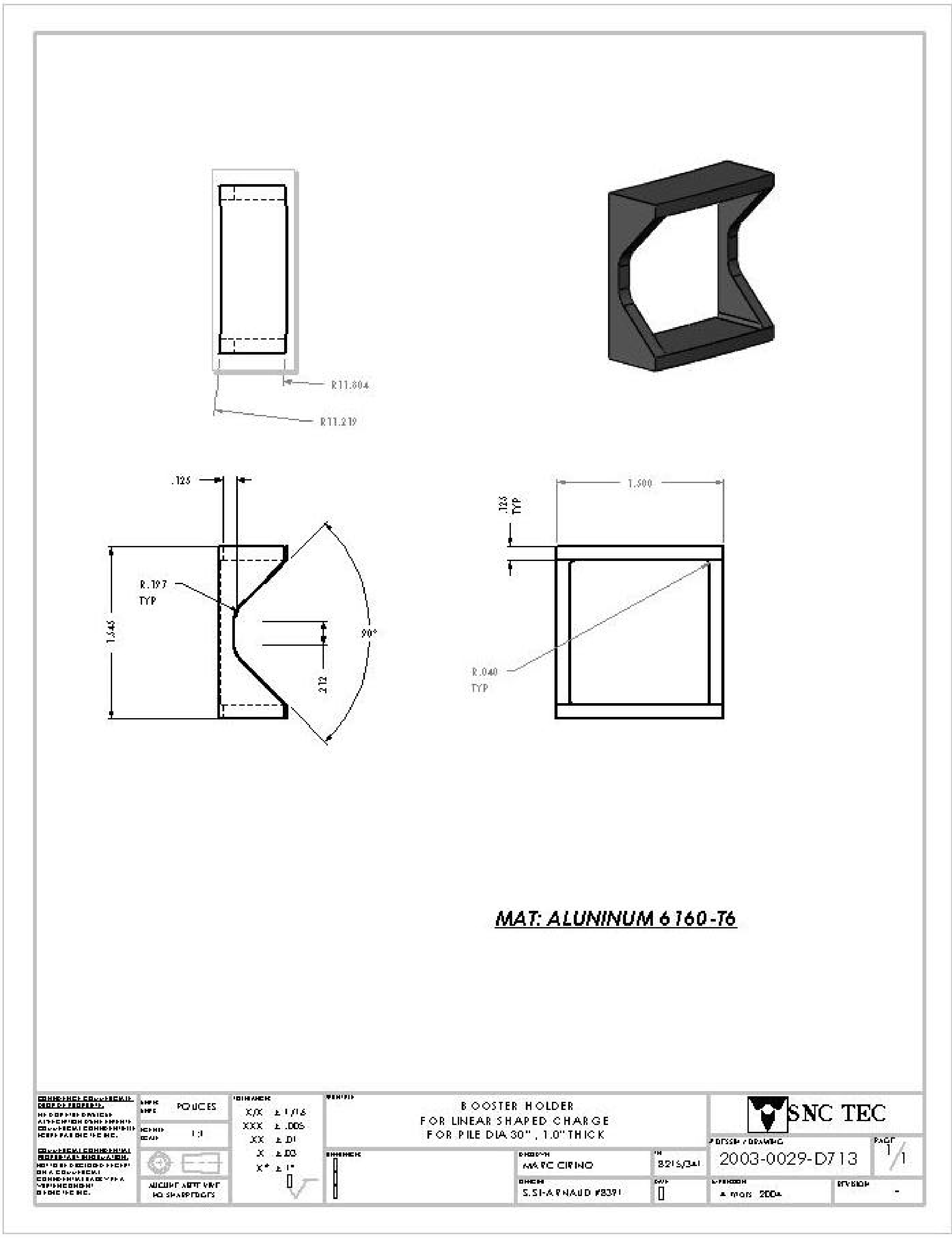

R11.804
R11.219
.125
R.197
TYP
1.545
90°
.212
1.500
.125
TYP
R.040
TYP
MAT: ALUNINUM 6160-T6
POUCES
1:1
X/X ± 1/16
XXX ± .005
.XX ± .01
.X ± .03
X° ± 1°
BOOSTER HOLDER
FOR LINEAR SHAPED CHARGE
FOR PILE DIA 30", 1.0" THICK
SNC TEC
2003-0029-D713
1/1
MARC CIRINO
S.ST-ARNAUD #8391

Annex G

Gulf of Mexico test plan

SNC TEC

PLAN D'ESSAI / *TEST PLAN*

TITRE DE L'ESSAI / *TEST TITLE*:	**Test of linear shape charge on piles in the Gulf, project MMS**		
Demandeur / *Requested by:*	Denis Saint Arnaud	**No. de l'essai /** *Test number:*	647-005-TEP-DET
Endroit de l'essai / *Test location:*	Mexico Gulf LA	Révision / *Revision:*	1
Date émise / *Date submitted:*	September 2003	Projet, Produit / *Project, Product:*	MMS
Date requise / *Date required:*	October 2003	No. Work Order / *Work Order No.:*	MP19400

PRÉSENCE DU DEMANDEUR OU DÉLÉGUÉ/ *REQUIRED PRESENCE OF AUTHORIZED PERSON:*	☒ OUI, NOM / *YES, NAME*	☐ NON REQUIS / *NO*

RUBRIQUES OBLIGATOIRES / *MANDATORY INFORMATION:*

1. **BUT /** *AIM:*

The first aim of these tests is to confirm that LSC mounted in appropriate casings will entirely severe 30"ø piles on actual platforms in the Gulf.

The second aim is to take blast measurements and data on the test environment requested by MMS according to parameters agreed with them.

2. **PROCÉDURES À SUIVRE /** *TEST PROCEDURE*:

Mount the linear shape charge along with filled booster holders inside the casings set-up ensuring correct standoff with the standoff blocks.

Close the casing and make them watertight with the Loctite #30507 material

Assemble initiation system over the casing.

Take measurements on the environment where the test is preformed (water salinity and temperature, data on the mud, …)

Evacuate area, connect initiation system and perform the pile severing test.

Obtain blasting performance data (Peak pressure, Impulse and Energy Flux)

Evaluate sectioning capability of the charge including depth and shape of penetration.

3. **MESURES DE SÉCURITÉ PARTICULIÈRES /** *SPECIFIC SECURITY MEASURES:*

a) **Mesures de sécurité particulières**
1.1D explosive manipulation. Use of appropriate protection shield and distance.
Following testing agency safety procedure.

b) **Analyse de risques spécifique à l'essai**

☐ **NON APPLICABLE /** *NOT APPLICABLE*
☒ **CONFORME À L'ANALYSE DE RISQUES DÉTAILLÉE NO. : /** *MEETS THE RISK ANALYSIS No.*
☐ **NON CONFORME À L'ANALYSE DE RISQUES DÉTAILLÉE NO.: /** *DOES NOT MEET THE RISK ANALYSIS No.*

NOMS DES PARTICIPANTS / *ATTENDEES NAME*

Nom / Département :
Name / Department :

Indiquer les changements/ *Modifications :*

Chef de projet / *Chief of the project*

Directeur responsable du projet / *Project Manager*

4. COMPOSANTES CRITIQUES UTILISÉES POUR L'ESSAI SONT CONFORMES / *CRITICAL COMPONENTS USED ARE CONFORM :*

☒ **N/A** ☒ **OUI/***YES* ☐ **NON/***NO*

Si non, donner la raison / *If not give the reason:*

RUBRIQUES APPLICABLES / ***APPLICABLE INFORMATION:***

	A	N/A		A	N/A
Produits à évaluer / *Product to test*	☐	☐	Armes, Équipement à utiliser / *Weapon, Equipment*	☒	☐
Charges propulsives / *Propelling charge*	☐	☒	**Critères d'acceptation /** *Acceptance criteria*	☒	☐
Données à recueillir / *Measurements*	☒	☐	**Autres rubriques /** *Other information*	☐	☒
Dessins applicables / *Applicable drawings*	☒	☐	**Références /** *References*	☒	☐

Product to test

First Pier has three piles of 30"ø, 1" thickness wall and has one well
First Pier will be severed during tests #1 to 4. Those tests will be conducted in one operation with only a short delay between them.

Table #1: Linear shape charge for 30"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
1	RDX	Curved charge ~21" long for 30"ø pile	Curved for 30"ø pile	1.25 inches	Pile 30" 1" thickness wall Nonel initiator	Four

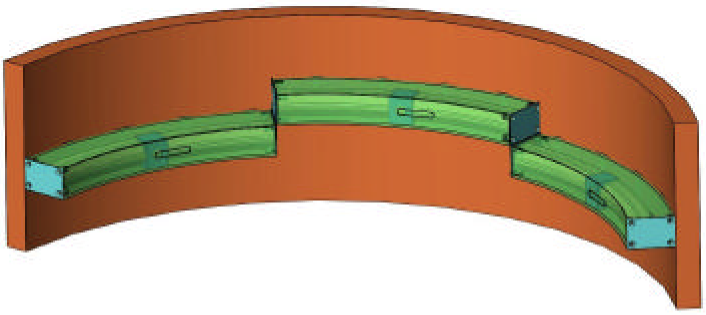


Table #2: Linear shape charge for 30"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape	Casing	Standoff	Required	Quantities

		and length			accessories	
2	RDX	Curved charge ~21" long for 30"ø pile	Curved for 30"ø pile	1.25 inches	Pile 30" 1" thickness wall Nonel initiator	Four

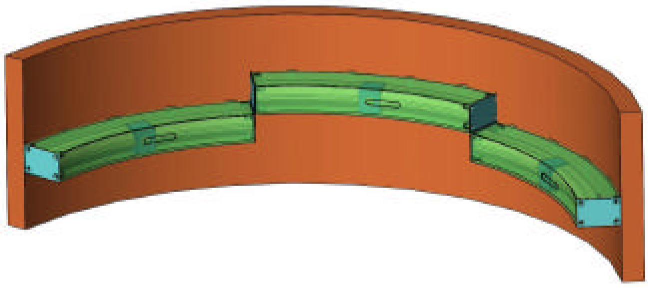


Table #3: Bulk charge 50 pounds for 30"ø pile non enclosed. To get comparative data with LSC testing. Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
3	RDX	N/A	N/A	N/A	Pile 30" 1" thickness wall Nonel initiator	One

Table #4: Bulk charge 50 pounds for 16"ø or 24"ø well non enclosed. To get comparative data with LSC testing.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
4	RDX	N/A	N/A	N/A	Well 16 or 24" Nonel initiator	One

Second Pier has three piles 30"ø, 5/8" thickness wall and has one well
Second Pier will be severed during tests #5 to 8. The tests will be conducted in one operation with only a short delay between them.

Table #5: Linear shape charge for 30"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
5	RDX	Curved charge ~21" long for 30"ø pile	Curved for 30"ø pile	1.25 inches	Pile 30" 5/8" thickness wall Nonel initiator	Four

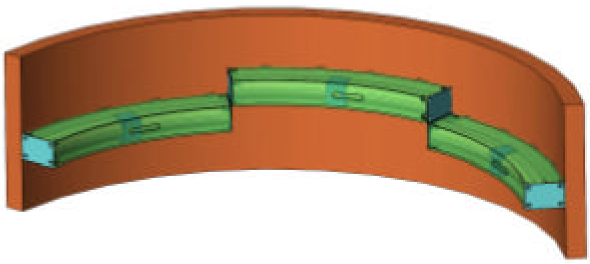


Table #6: Linear shape charge for 30"ø pile enclosed in casing to confirm initiation system location and best way to build it.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
6	RDX	Curved charge ~21" long for 30"ø pile	Curved for 30"ø pile	1.25 inches	Pile 30" 5/8" thickness wall Nonel initiator	Four

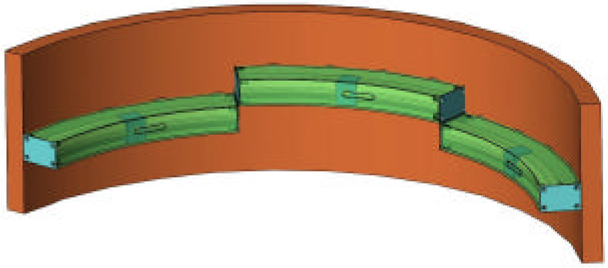


Table #7: Bulk charge 50 pounds for 30"ø pile. To get comparative data with LSC testing. Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
7	RDX	N/A	N/A	N/A	Pile 30" 5/8" thickness wall Nonel initiator	One

Table #8: Bulk charge 50 pounds for one well 16" or 24"ø non enclosed. To get comparative data with LSC testing.

Location at 15 feet below mudline.

Tests #	Explosive	Charge shape and length	Casing	Standoff	Required accessories	Quantities
8	RDX	N/A	N/A	N/A	Well 16 or 24" Nonel initiator	One

Table #9 : Results

Test #	Explosive	Number of charges	Casing damages	Target damages	Photo	Sonalysts measurements
1	RDX eng LSC	4				

2	RDX eng LSC	4				
3	RDX bulk	1	N/A			
4	RDX bulk	1	N/A			
5	RDX eng LSC	4				
6	RDX eng LSC	4				
7	RDX bulk	1	N/A			
8	RDX bulk	1	N/A			

Equipment

Test # 1 :	30"ø pile 1" thickness wall Linear shape charge filled with RDX & casing curved for the pile Booster system Scorpion System Initiation system
Test #2 :	30"ø pile 1" thickness wall Linear shape charge filled with RDX & casing curved for the pile Booster system Scorpion System Initiation system
Test #3 :	30"ø pile 1" thickness wall One Bulk charge 50 pounds with RDX Booster system Initiation system
Test #4 :	16 or 24"ø well One Bulk charge 50 pounds with RDX Booster system Initiation system
Test # 5 :	30"ø pile 5/8" thickness wall Linear shape charge filled with RDX & casing curved for the pile Booster system Scorpion System Initiation system
Test # 6 :	30"ø pile 5/8" thickness wall Linear shape charge filled with RDX & casing curved for the pile Booster system Scorpion System Initiation system
Test # 7 :	30"ø pile 5/8" thickness wall One Bulk charge 50 pounds with RDX Booster system Initiation system
Test # 8 :	One well 16 or 24"ø One Bulk charge 50 pounds with RDX Booster system Initiation system

Acceptance criteria

Test is considered successful if target is entirely cut.

Measurements

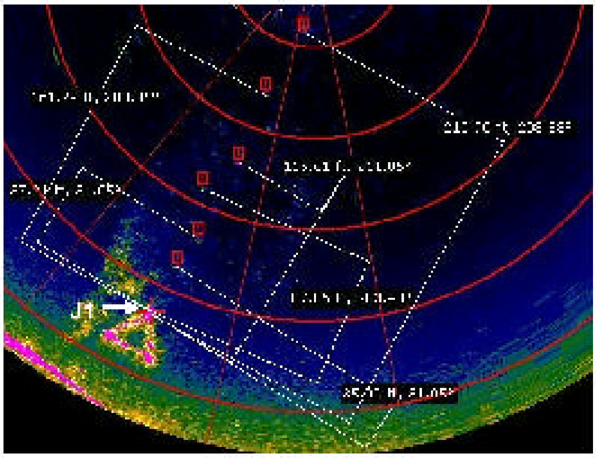
After each tests target must be photographed to evaluate damages.
Targets must be cut perpendicularly to jet propagation.
Any remaining attachment must be photographed for evaluation of depth and shape of penetration..
Measurement must be done on Peak pressure, Impulse and Energy Flux.

Annex H

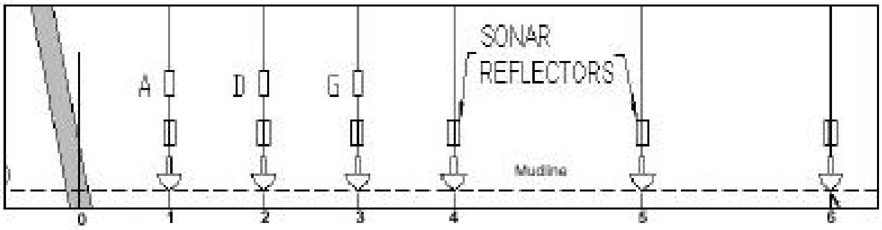
Gulf of Mexico testing – Sonar localization report

Mesotech – 1000 Readings for Structure #97; Second Array Deployment – November 22, 2003

Using the Kongsberb-Simrad, Mesotech-1000, Sector-Scanning Sonar, MMS personnel took seabed-level distance measurements between the sonar reflectors positioned at the bottom of each downline of Sonalysts' transducer array and the primary tripod leg (from which the array was connected – J1). Scanning work commenced once the array was fully deployed and the workboat (Capt. W.A. Bisso Jr.) was secured in position using the forward anchor assembly and aft port and starboard winches. After deploying the sonar from the port side, initial scans were taken to establish reference points and the tripod's location. Each reflector was then detected using a process of increasing the gain (power output) of the sonar and zooming in on the targets' location; electronically tagging each reflector's location using the MS-1000 software. Once all six (6) reflectors were located and tagged, the software package allowed for the measurement of each reflector position back to the tripod leg (see picture right).



Reflector	Jacket Leg 1 (J1)
1	35.00'
2	57.21'
3	87.06'
4	115.61'
5	161.29'
6	210.96'



The Mesotech work conducted on the Derrick Barge, Boaz, coincided with the readings taken for reflectors 1 through 4, but propwash from a stationing tug prevented accurate measurements for farfield reflectors 5 and 6. Because of the close relative distance between the MMS Mesotech and reflectors 5 and 6, the propwash did not hinder accurate measurements. In addition to the picture, measurements from the center of Jacket Leg 1 (J1) out to each respective sonar reflector are included in the table above.

Annex I

Gulf of Mexico testing – Sonalysts test report

Revised 04-04-30

Blast Measurements
on
Huber #97 and #120 Platform Decommissioning

November 21-23, 2003

Prepared for:

SNC Technologies Corporation
5, montee des Arsenaux
Le Gardeur, QC, Canada
J5Z 2P4

Prepared by:

Sonalysts, Inc.
215 Parkway North
Waterford, CT 06385

Introduction

Measurements were made on November 22nd and 23rd on Huber Platforms #97 and #120 to determine the underwater shock pressure pulse parameters of Peak Overpressure, Specific Impulse and Energy Flux Density at each of 12 transducer positions resulting from explosive cutting of the piling legs and well conductors. On platform #97, three piling legs were targeted (there was no well conductor at this location) with the first in trigger sequence being a 4.6-pound engineered charge and the remaining two 50-pound bulk charges. On platform #120, where there was a well conductor, the first piling triggered was again a 4.6 pound engineered charge, with the remaining three 50-pound bulk charges. Collected data was compared to ARA model [1] projected levels. Transducer location data was measured by both Bisso Marine and Minerals Management Service (MMS) staff, using a Mesotech MS-1000 sector-scanning sonar, in order to confirm the actual position of the array.

Huber #97 (left) and #120 (right)

[1.] Dzwilewski, Peter T. and Fenton, Gregg, Shock Wave / Sound Propagation Modeling Results for Calculating Marine Protected Species Impact Zone During Explosive Removal of Offshore Structures, Applied Research Associates, Inc., January 20, 2003.

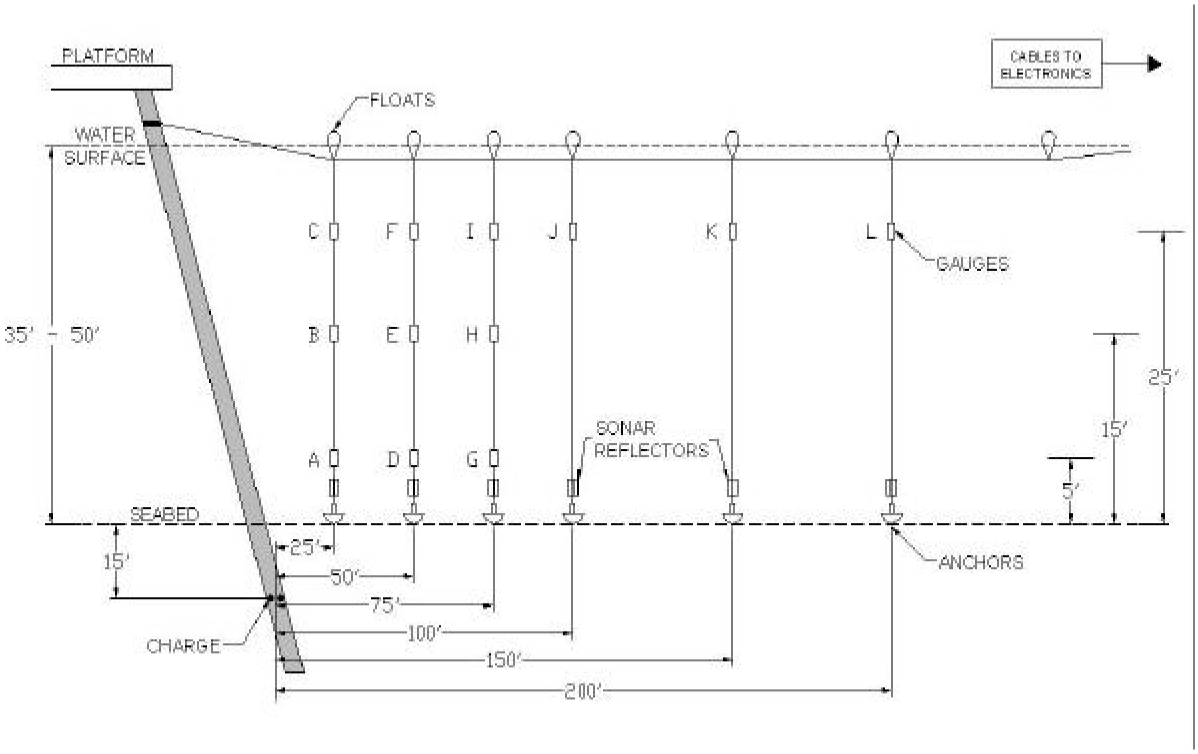
The measurement array was deployed off the stern deck of the Capt. W. A. Bisso, Jr. 150' workboat, supplied by Bisso Marine. After the first array deployment on Friday November 21st, it was determined that the piling where the Scorpion (and engineered charge) would be deployed was not fully jetted, so the array had to be retrieved after being in the water for over 6 hours. The array was redeployed at dawn of the following morning, November 22nd, and the targets were exploded. The calibration test charge showed that three transducers were not working. Shock data and transducer location scans were taken and successfully stored. The engineered charge did not fully cut the piling, so the target had to be exploded again prior to removing the structure.

On the following day, November 23rd, transducers that were found detached from the previous day's measurements were repaired. The cal test charge revealed that all transducers but one were working. Unlike the previous day, there was much difficulty in the array deployment at Huber #120 due to 4' to 6' seas, a snapped tie line, and the leakage in the air-driven winches on the Jr. When the array was finally deployed, a tug assisted the Jr. to keep it in position to protect the arrays. The targets were then exploded and the shock pressure data recorded on the DL750 ScopeCorder. When the operator went the stop the measurement (to store the data), the ScopeCorder restarted and erased the data. The ScopeCorder uses the same switch to start and stop data acquisition and when a new measurement is started, previous data is erased from the buffer. It is not clear if the switch bounced (electro-mechanically) or the operator double-hit the switch, possibly due to the high vibration levels and wave action swaying on the Jr. The operator did see the first four channels of the data and wrote down the approximate levels to at least preserve some of the data. In addition, prop wash from the tug and Jr. workboat was so strong that neither the Boaz derrick barge nor MMS sidescan sonars could successfully get complete array position data.

The engineered charge did not fully cut the piling again, and a backup charge had to be employed.

Instrumentation

Measurements were made using a transducer array consisting of 12 PCB W138A Underwater Blast Pressure Transducers (tourmaline) that were configured with the first three downlines having transducers (3) at 5', 15' and 25' vertically above the mudline. These nearfield downlines were positioned at horizontal distances of 25', 50', and 75' from the charge position. The last three transducers were positioned at horizontal distances of 100', 150', and 200' (farfield), with each one at 25' vertically above mudline. The blast transducers were powered by PCB ICP power supplies, and then fed into a Yokogawa DL750 ScopeCorder where data was measured and stored for later retrieval.



For depth, speed of sound (derived from conductivity/salinity), and temperature measurements, a RBR XR-420 CTD logger was used. At #97, both the Jr. and Boaz reported depth soundings of 50 feet: these were confirmed by the CTD. The sounding depth of 40 feet was also confirmed by the CTD at #120 (wave action was ±3', so the CTD readings were within wave action fluctuations). Following is the CTD data collected for #97 and #120:

Date	Time	Cond (mS/cm)	Temp (°C)	Pressure (deciBars)	Depth (m)	Speed of Sound (m/sec)
11/21/03	8:55:30	42.79	23.17	25.37	15.11	1523.39
11/23/03	14:44:40	43.29	23.03	21.59	11.36	1523.48

Measurements

Shock wave time data was gathered for nine of twelve channels at Huber #97 decommissioning for one 4.6 pound engineered charge and two 50-pound bulk charges. Of the twelve transducers, three did not work: transducer E (50' distance, 15' above mudline); transducer J (100' distance, 25' above mudline); and transducer K (150' distance, 25' above mudline). Actual array position data was also gathered using both the Boaz's and Jr.'s (MMS) sector-scanning sonars, and this data has been integrated into the following data tables.

With regard to #120, only data for the 50-pound charges (3) was "remembered" from the brief visual display and only for the first four transducers. The 4.6-pound engineered charge levels were observed to be considerably lower than the bulk charge levels.

Peak Overpressure: psi								
Transducer	**Slant Range Leg 1**	**50 lb ARA**	**50 lb 1 Meas**	**Slant Range Legs 2+3**	**50 lb ARA**	**50 lb 2 Meas**	**4.6 lb ARA**	**4.6 lb Meas.**
A_R25V5	40.3	1014.4	244.1	75.4	467.2	137.9	168.5	139.2
B_R25V15	46.0	863.0	281.6	78.7	443.5	167.1	160.0	140.3
C_R25V25	53.1	723.5	279.0	83.0	415.9	98.2	150.0	78.8
D_R50V5	60.6	615.3	192.5	96.4	346.3	90.9	124.9	86.7
F_R50V25	69.7	521.1	211.6	102.4	322.1	134.2	116.2	74.4
G_R75V5	89.3	384.5	151.4	125.2	251.6	64.1	90.8	45.5
H_R75V15	92.1	369.5	137.7	127.2	246.8	82.7	89.9	93.2
I_R75V25	95.8	352.6	83.3	129.9	240.8	118.8	86.9	119.0
L_25R200	214.7	131.8	41.2	249.9	108.3	26.8	39.1	10.1

Peak Overpressure Levels for #97 (ARA projected versus measured)

Measurements on #120 showed that the Peak Overpressure levels on the first four transducers (A through D) were on the order of 400 to 500 psi for the three 50-lb bulk charge shots. This is higher than that measured at #97, but still lower than the ARA predictions for a 35 foot slant range (no actual measured distance data is available for #120).

Impulse: psi•s								
Transducer	**Slant Range Leg 1**	**50 lb ARA**	**50 lb 1 Meas**	**Slant Range Legs 2+3**	**50 lb ARA**	**50 lb 2 Meas**	**4.6 lb ARA**	**4.6 lb Meas.**
A_R25V5	40.3	0.399	0.140	75.4	0.196	0.069	0.045	0.016
B_R25V15	46.0	0.354	0.193	78.7	0.188	0.017	0.043	0.012
C_R25V25	53.1	0.310	0.183	83.0	0.179	0.017	0.041	0.012
D_R50V5	60.6	0.275	0.108	96.4	0.156	0.054	0.036	0.010
F_R50V25	69.7	0.243	0.018	102.4	0.147	0.019	0.034	0.012
G_R75V5	89.3	0.193	0.081	125.2	0.122	0.054	0.028	0.006
H_R75V15	92.1	0.188	0.066	127.2	0.120	0.013	0.028	0.010
I_R75V25	95.8	0.181	0.044	129.9	0.118	0.016	0.027	0.008
L_25R200	214.7	0.087	0.030	249.9	0.063	0.022	0.015	0.004

Impulse Levels for #97 (ARA projected versus measured)

Energy Flux Density: psi•in								
Transducer	**Slant Range Leg 1**	**50 lb ARA**	**50 lb 1 Meas**	**Slant Range Legs 2+3**	**50 lb ARA**	**50 lb 2 Meas**	**4.6 lb ARA**	**4.6 lb Meas.**
A_R25V5	40.3	34.695	3.589	75.4	6.735	0.813	0.700	0.132
B_R25V15	46.0	26.337	5.526	78.7	6.143	0.138	0.640	0.097
C_R25V25	53.1	19.499	4.353	83.0	5.482	0.078	0.574	0.055
D_R50V5	60.6	14.794	1.756	96.4	3.963	0.419	0.420	0.038
F_R50V25	69.7	11.144	0.162	102.4	3.486	0.105	0.371	0.054
G_R75V5	89.3	6.636	1.009	125.2	2.252	0.280	0.244	0.013
H_R75V15	92.1	6.201	0.678	127.2	2.177	0.047	0.236	0.057
I_R75V25	95.8	5.725	0.259	129.9	2.083	0.082	0.226	0.054
L_25R200	214.7	1.070	0.090	249.9	0.506	0.051	0.058	0.004

Energy Flux Density for #97 (ARA projected versus measured)

Measured data shows that peak pressure levels are quite lower than predicted by the ARA model (this was also experienced in the quarry measurements in July). In addition, some of the transducers further away from the mudline experienced higher levels than near mudline (5' above) counterparts. This was also the case for #120 where the highest level (about 500 psi) was observed at transducer C (25' distance and 25' above mudline). It may be that the shock levels from the structures above mudline and closer to the surface are higher due to the lower impedance near the top because of lack of mud/silt. Further investigation and many more data points will be needed to determine if this in an anomaly or is consistent among all structure types and condition. Also of note is the substantial difference in data results for the two 50 lb charges. Again, there are not enough data points to understand the reason for difference.

Note: Slant ranges are in feet. A time constant multiplier of 6.7 was used for Impulse and Energy Flux Density calculations.

Lessons Learned

There were many valuable lessons learned in this study that can be carried into any future studies that may be done on the Gulf structure decommissioning. Following is a list of some of these issues. While not exhaustive, the listed items, if implemented for any follow up or similar study, will help to insure better array deployment and data gathering.

• Anchoring of the transducer array was not optimal. The original plan had been to use a large clump anchor with a large float at the far end of the array and a direct attachment to a piling at the originating end with a heavy aircraft cable strung in between from which down lines would be hung. This plan was changed and the array executed from the stern deck of the 150' Jr. workboat. The Jr. was unable to keep its winches in check, even under the smoother seas at #97, and required a tug on both #97 and #120 to hold her position. This, plus the severe vibration on board the Jr., proved very detrimental to array deployment and subsequent measurements. Either a more powerful workboat with properly working winches or the original clump anchor arrangement will be necessary for the success of future measurements and array deployment.

• Prop wash from the Jr. and the assisting tugboat on #120 overshadowed the sidescan sonars (both Bisso and MMS systems) to the point where no data could be measured regarding transducer position. Transducer position verification is an important part of the subject measurements and sidescan sonar provides one of very few means to do so. This, in concert with the former issue, shows the need to implement a clump anchor arrangement with external (still a workboat) servicing of the array for deployment.

• Array deployment using multiple reels was difficult. The Jr. had no reasonable means (very few tiedowns) of anchoring a cable reel rig, and although the cable reels used were satisfactory for a limited amount of deployments, future deployments will benefit from a multi-reel system that can be anchored to the work deck of the host workboat.

• Quality measured data (blast pressure transducer) was lost (not stored) at #120. There are limited (only two found) devices capable of capturing time data at such a high rate (500kHz) for 12-16 channels with the needed high dynamic range. Unfortunately, the DL750 that was used has a data acquisition switch that is the same for the start and stop function. Under lab conditions, this is acceptable. Under adverse conditions such as the high levels of ship vibration and large swells (4-6' seas) encountered at #120, this is difficult at best (as demonstrated when an experienced user "hit" the switch twice or it bounced mechanically). This shows the need for a redundant system. This could be a second DL750 in parallel, or another less expensive and lower bandwidth backup storage system. This is a must-address issue prior to any further measurements.

• Instrumentation was exposed to the elements. The weather did not present any major problems as far as the measurement instrumentation, but it could have as the workboat had no place to shelter the equipment. Both the data logger and sidescan sonar systems will need proper shelter (a secure place on the workdeck where the equipment can be installed for numerous array deployments) to protect it from rain and sun. Also, vibration/shock mounting can be imp lemented. This will help to reduce deployment time, aid in viewing data as it comes in (no sun visors needed) and will protect the equipment from the environment.

• Communications systems were non-existent. One of the most difficult areas was communication. The arrays were difficult to deploy and needed three to four persons to do it properly. In the meanwhile, the Jr. was trying to maintain the position needed for the array to be fed out. Only hand signals and yelling were available as means of communication. Furthermore, communication with the derrick barge, especially just prior to the shots, was minimal. Any future work will require better communication systems to be in place. High quality walkie -talkies would be good, but noise canceling communications headsets would be a much better alternative unless a reasonably quiet and strong workboat can be secured.

• Array downline ropes were stretching and causing undue stress on pressure transducer cabling. The next version of the array should implement coated steel cable for downlines instead of rope. The difficulty will be having an array that can be reconfigured with reasonable effort for varying depths at different structures. This is a challenge for the downlines, and cabling to the transducers and instrumentation, and will need to be carefully considered prior to any new measurements.

• Many more data points are needed before similitude equations can be formulated with confidence. Furthermore, since the time waveforms vary considerably, it will be important to try to establish theories or demonstrable causes for the variances.

Annex J

Gulf of Mexico testing – Soil sampling data Gulf of Mexico testing Bests available copies

SOIL AND FOUNDATION INVESTIGATION
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

* * * * *

Report To:

TENNECO OIL COMPANY

Lafayette, Louisiana

* * * * *

Submitted By:

FUGRO INTER, INC.

Houston, Texas

* * * * *

February 1984

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FUGRO INTER, INC. CONSULTING GEOTECHNICAL ENGINEERS

FUGRO

10165 Harwin, Suite 170, Houston, Texas 77036
Phone: (713) 777-2641; Telex: 775494

February 10, 1984
Report No. 83-1109

Tenneco Oil Company
Eastern Division
Post Office Box 39200
Lafayette, Louisiana 70503

Attention: Mr. J.V. Simon

SOIL AND FOUNDATION INVESTIGATION
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

Gentlemen:

Submitted here is the report on our study of soil and foundation conditions at the above location. This study was authorized by Mr. H.C. Melancon per telex dated December 14, 1983.

Previously, a jack-up leg penetration study was conducted for the RANDOLPH YOST based upon data obtained during the field investigation. The results were submitted in our report dated December 27, 1983. Due to the possibility of a punch-through occurring during penetration, the preloading operation was observed and leg penetrations monitored by an engineer from Fugro Inter.

The following report contains the results of the leg penetration monitoring, as well as final design information for axial load capacities and lateral soil resistance (p-y) data for 36- and 48-inch OD driven pipe piles. A complete description of the field investigation and laboratory testing program is also included.

We appreciate the opportunity to be of service to you and look forward to continued association on future projects. Please call us if you have any questions.

Very truly yours,
FUGRO INTER, INC.

Charles F. Rickert
Staff Engineer

Vincent P. Baglioni, P.E.
Project Manager

CFR/VPB/kjt
Copies Submitted: 5

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ILLUSTRATIONS

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SUMMARY

An investigation was conducted to determine soil and foundation conditions at a proposed exploration site (Well No. 11) in Block 22, South Timbalier Area, Gulf of Mexico. Soil conditions were determined by drilling and sampling to a depth of 304 feet below the seafloor and field and laboratory tests were performed to determine pertinent physical properties of the foundation soils. At the time of the field investigation, the average measured water depth was 49 feet.

The foundation soils at the boring location consist of soft to stiff olive gray clay to a depth of 122 feet below the seafloor underlain by alternating layers of medium dense to dense olive gray sandy silt and silty fine sand to a depth of 282 feet followed by stiff to very stiff olive gray clay to the boring termination depth of 304 feet.

A leg penetration and rig foundation stability study was performed for the jack-up RANDOLPH YOST and reported in a separate report dated December 27, 1983. Based on this study, final penetrations of 45 to 55 feet were predicted. Because of a possible punch-through, the preloading operation was observed and leg penetrations monitored by an engineer from Fugro Inter. A punch-through did not occur and a maximum penetration of 43 feet was recorded.

Ultimate compressive and tensile capacities and p-y data were computed for 36- and 48-inch OD pipe piles. An ultimate compressive capacity of 5300 kips is available for the 48-inch OD pipe pile at the boring termination depth.

Higher driving resistance should be anticipated while driving through the medium dense to dense silts and sands between 122 and 282 feet below seafloor. A driveability analysis is recommended to determine minimum pile wall thickness and hammer size.

The ultimate mudline bearing capacity is 2500 pounds per square foot.

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INTRODUCTION

The investigation reported herein was performed for Tenneco Oil Company for a proposed exploration site (Well No. 11) located approximately 600 feet from the West line (FWL) and 2100 feet from the South line (FSL) of Block 22, South Timbalier Area in the Gulf of Mexico.

The objectives of the investigation were to determine subsurface conditions at the proposed offshore exploration site, predict leg penetrations for the jack-up exploration rig RANDOLPH YOST, and develop criteria and recommendations for design and construction of a pile foundation for a future fixed platform. These objectives were accomplished as follows:

1. A boring was drilled to determine soil stratigraphy at the location.
2. Field and laboratory tests were performed to define the pertinent physical characteristics of the soil.
3. Engineering analyses based on an assessment of the field information and laboratory tests were performed to estimate leg penetration and assess foundation stability for the jack-up rig RANDOLPH YOST. Criteria and recommendations for design and construction of 36- and 48-inch OD pipe pile foundations were also developed.

The results of the leg penetration study were presented in a report to Tenneco Oil Company dated December 27, 1983. The preloading operation and leg penetrations were monitored by an engineer from Fugro Inter between December 30, 1983 and January 3, 1984.

Subsequent sections of this report contain brief descriptions of the field investigation, laboratory testing program, and the general soil conditions at the site. Leq penetration monitoring results are presented. Recommendations are included on axial pile capacities, factors of safety, lateral soil resistance, pile installation and mudline bearing capacity.

FIELD INVESTIGATION

The field program consisted of investigating soil and foundation conditions to a depth of 304 feet below the seafloor at the approximate location of the proposed Well No. 11. A single soil boring was drilled at 619 feet from the West line and 2144 feet from the South line of Block 22, South Timbalier Area. The corresponding Louisiana South Zone Coordinates are x = 2,349,989 and y = 121,716. The boring location was established by Odom Offshore Surveys, Inc., contracted by Tenneco Oil Company. The drilling and soil sampling operation was conducted from the jack-up barge, M/V WAYNE DICKENSON, owned and operated by Otis Engineering Corporation. A prior attempt had been made to perform the field investigation from the four-point moored M/V KARA SEAL, but due to existing pipelines and structures very near to the intended location, the attempt was aborted.

The water depth was measured with the ship's echo sounder, by the length of the drillstring and with a wireline technique. Average water depth using these procedures was 49 feet. These measurements were made at approximately 0500 hours on December 21, 1983, and they have not been corrected for tidal variations. Using the wireline technique, a weight is connected to a wireline and lowered slowly to the mudline. A depthometer records the amount of wireline reeled off when the weight reaches the mudline. The procedure was repeated until a difference between two consecutive water depth measurements was less than one foot.

The boring was drilled through an open well, fabricated through the deck and hull of the M/V WAYNE DICKENSON, with a conventional rotary drilling rig, using 3-1/2 inch OD IF drill pipe with an open-ended bit. Samples were taken semi-continuously (about 3-foot intervals) to a depth of 42 feet and at 10-foot intervals thereafter to a termination depth of 304 feet. Soils were sampled with a 2-1/2 inch OD thin-walled tube sampler. The samplers were driven with a 165-lb. sliding hammer attached to the head of the sampling apparatus. The sampling unit was lowered through the opening in the drill string and operated with a wireline. The hammer was raised with the wireline approximately five feet and dropped a sufficient number of times to obtain 18 to 24 inches of sampler penetration or until driving resistance became excessive. The actual length of each sample was measured after retrieval of the sampler and this value was used to compute the average number of blows per foot of penetration required to advance the sampler at that depth.

The soil samples were extruded from the sampler, examined and visually classified by a soils engineer and technician onboard the drilling vessel. A part of each cohesive sample was tested in the laboratory onboard the M/V WAYNE DICKENSON to determine soil shear strength and unit weight. Remaining portions of the cohesive samples and a part of each cohesionless soil sample were then sealed in moisture-tight containers for transportation to our laboratory in Houston.

Descriptions of the soils encountered in the boring are given on the left-hand portion of the Log of Boring and Test Results (Plates 1 and 2), along with a graphical symbol for the various types of soil encountered and sampler blowcount information. A key to soil classification and symbols used on the log is presented on Plate 3.

A chronological summary of field activities for the soil investigation performed at this location is given on Plate 4.

FIELD AND LABORATORY TESTS

The field and laboratory testing program was designed to evaluate the pertinent physical and engineering properties of the foundation soils encountered at the boring location. The testing program was performed in two phases: (1) field strength and unit weight tests were run on cohesive soils in the laboratory onboard the drilling vessel, and (2) soil identification-classification tests and additional strength tests were performed in our Houston laboratory to gain more detailed information on the pertinent physical properties of all soils encountered in this investigation.

Onboard the drilling vessel, miniature vane shear tests were run prior to extruding samples from the thin-walled tube sampler. Strength tests were also performed using a Torvane device. The detailed laboratory strength testing program included unconfined and triaxial compression tests.

Laboratory test results are presented graphically on the Log of Boring and Test Results (Plates 1 and 2), and a tabulation of numerical test data is given on the Summary of Test Results (Plate A-1) in Appendix A. Procedures for all tests are presented in Appendix A, together with stress-strain curves for selected strength tests on clay samples and grain size distribution curves and triaxial compression test data for granular soils.

GENERAL SOIL CONDITIONS

Soil Stratification

A detailed description and summary of test results of the soils encountered at this site are shown on the Log of Boring and Test Results (Plates 1 and 2). The foundation soils at the boring location can be divided into seven generalized strata as follows:

Stratum	Depth, Ft. From	To	Soil Description
I	0	122	Soft to Stiff Olive Gray Clay
II	122	172	Medium Dense Olive Gray Sandy Silt
III	172	202	Medium Dense Olive Gray Silty Fine Sand
IV	202	252	Medium Dense Olive Gray Sandy Silt
V	252	282	Dense Olive Gray Silty Fine Sand
VI	282	304	Stiff to Very Stiff Olive Gray Clay

Minor textural and color variations and inclusions of other types of soil are noted on the Log of Boring and Test Results (Plates 1 and 2).

The previous leg penetration predictions and recommendations for pile design presented in this report are based on the assumption that soil stratigraphy and conditions disclosed by this foundation boring are continuous throughout the general area of the proposed exploration site. Consideration of possible stratigraphic changes, faulting, or other differences that could influence leg penetration, jack-up stability and fixed platform foundation design is beyond the scope of this investigation.

Soil Properties

Based on an evaluation of field and laboratory results, a curve of the shear strength variation with depth was developed for the cohesive soil at the

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site. The interpreted shear strength variation profile is shown on the soil properties plot on Plate 6 as well as on the Log of Boring and Test Results (Plates 1 and 2) as a heavy solid line. The average submerged unit weights between the indicated depth intervals are also provided in Plate 6.

Design strength parameters for the granular material encountered at this site were selected on the basis of grain size distribution, sampler blowcount information and the presence or absence of clay seams or pockets in these strata. Interpreted soil parameters and submerged unit weights for these strata have also been summarized on Plate 6.

ANALYSES AND RECOMMENDATIONS

Jack-Up Leg Penetration

A detailed description of the leg penetration/foundation stability evaluation was presented to Tenneco Oil Company in our report dated December 27, 1983 entitled "Jack-Up Leg Penetration Study, Reading & Bates RANDOLPH YOST, Block 22, South Timbalier Area, Gulf of Mexico". Within the upper clay stratum, a gas-charged sandy silt zone was encountered between 43 and 48 feet below seafloor. Because the lower-bound shear strength envelope indicated that there could be enough leg penetration to cause the spud cans of the jack-up to temporarily stop penetrating due to this silt zone, a sudden, additional penetration or "punch-through" was a possibility during preloading. Since a punch-through was considered possible, the preloading operation and actual leg penetrations were monitored by an engineer from Fugro Inter during the jack-up and preloading of the RANDOLPH YOST at the Well No. 11 site.

Based on the range of interpreted shear strength selected prior to the arrival of the rig on location, a final penetration with 100% preload was predicted to be from 45 to 55 feet from the mudline to spud can tip. If the observed penetrations were close to the lower bound prediction of 55 feet, then the chances of a punch-through would be increased. The actual maximum observed spud can penetration was 43 feet. The laboratory testing program performed subsequently confirms the previously selected upper bound shear strength as the design profile.

Recent observations in soil conditions simlar to those encountered at this site indicate that, on occasion, the spud can holes do not collapse and fill the void created as they penetrate. This collapse may occur at some period of time after initial penetration or not at all. Under certain conditions, penetrations may not reach those predicted because spud can holes have not collapsed as assumed in the analyses.

Since there were some gas bubbles observed in the vicinity of the aft spud cans, divers were brought in to inspect the seafloor to locate the source of the seepage. While the divers were down confirming that the main source of the seepage was the previously drilled soil boring, they also inspected the spud can holes and confirmed that the holes had not collapsed. This inspection was performed approximately 16 hours after the spud can holes were formed.

A summary of field activities for the leg penetration monitoring program is shown on Plate 5. Actual observed penetrations for the two aft legs are plotted over the predicted curve shown on Plate 7. The heavy dashed line shown on Plate 7 indicates the maximum influence that open spud can holes can have on penetrations at this site. As can be seen, there is a very good correlation between the observed penetration behavior for the aft legs and that expected for the open spud can hole condition. The bow leg, located approximately 200 feet Northeast of our soil boring, experienced a maximum penetration of 37 feet. Also shown in the lower left hand corner of Plate 7 is a Site Plan, illustrating the relative locations of the soil boring and the RANDOLPH YOST'S spud cans.

Axial Pile Capacity

The ultimate compressive (axial) load capacity (Q) of a pile for a given penetration is the sum of the skin frictional capacity (Q_s) and the end bearing capacity (Q_p):

$$Q = Q_s + Q_p = fA_s + qA_p$$

A_s and A_p represent the embedded pile surface (skin) area and pile end (total cross-sectional) area, respectively; f and q are the unit skin friction and unit end bearing resistance, respectively. The end bearing term (qA_p) in the equation is neglected when calculating ultimate tensile (pullout) load capacity of a pile. The API RP 2A Criteria (January 1982), described in Appendix B, was utilized in calculating axial pile capacity. The soil stratigraphy, interpreted strength parameters and submerged unit weights used in the axial pile capacity computations are presented on Plate 6. Variations of unit skin friction with depth are shown on Plate 6.

Unit end bearing variation with depth is also shown on Plate 6. These values were calculated using the expressions in Appendix B and represent values of unit end bearing at specified points. However, if at any depth, the end bearing capacity exceeds the cumulative frictional capacity, the total capacity at that depth is limited to twice the frictional capacity (i.e., friction along the outside of the pile plus the component along the internal plug). This situation can occur if granular sediments or overconsolidated clays are encountered at shallow depths. If such conditions prevail, an equivalent unit end bearing is computed based on end bearing capacity being equal to frictional capacity.

The results of the pile capacity analyses for 36- and 48-inch OD driven pipe piles are presented in the form of the pile capacity versus pile penetration curves on Plates 8 and 9. An ultimate compressive capacity of 5300 kips is available for a 48-inch OD pipe pile at this location at the boring termination depth of 304 feet.

Factor of Safety. The magnitude of the factor of safety to be used with the ultimate capacity should be selected after giving consideration to several factors: (1) storm frequency, (2) wave and current forces, (3) economic importance of the structure, (4) sensitivity of the structure to vertical movement, and (5) methods used in determining subsurface conditions and predetermining pile capacities. Assuming that the piles will be designed for environmental loading with appropriate drilling or producing loads, a factor of safety of 1.5 was used to generate the recommended capacity curves shown on

Plates 8 and 9. This factor of safety is consistent with recommendations in API RP 2A. Factors of safety appropriate for other loading conditions, such as for conductor piles, should be considered separately.

Lateral Soil Resistance. Behavior of foundation piles subjected to lateral and overturning loads will be evaluated with a computer program in which the lateral soil resistance (p) in pounds per linear inch, is expressed as a nonlinear function of pile deflection (y) in inches. The relationship of these parameters is a function of the soil stress-strain characteristics, depth, pile diameter, and soil shear strength. Development of the p-y values recommended in this report was based on Matlock's Criteria [1] for clays and Reese's Criteria[2] for cohesionless deposits.

The p-y values for 36- and 48-inch OD pipe piles presented on Plates 10 and 11 are for the soil strata encountered for the first 100 feet below the mudline. These data are given in tabular form to facilitate input into a computer program.

Pile Installation Considerations. Piles should be capable of being driven to a depth which will achieve a desired capacity without jetting or drilling. A significant increase in driving resistance should be expected while driving into the medium dense to dense sandy silts and silty sands below a pile penetration of 122 feet. We recommend that a driveability analysis be performed to determine minimum pile wall thickness and hammer requirements to permit the final penetration depth to be reached by driving alone.

---

(1) Matlock, Hudson, "Correlations for Design of Laterally Loaded Piles in Soft Clay", Presented at the Second Annual Offshore Technology Conference, Houston, Texas 1970.

(2) Reese, Lymon C., William R. Cox, and Francis D. Koop, "Analysis of Laterally Loaded Piles in Sand", Presented at the Sixth Annual Offshore Technology Conference, Houston, Texas, 1974.

Mudline Bearing Capacity. Mudline bearing capacity at this location was computed using the soil properties shown on Plate 6 and bearing capacity theory for shallow foundations. The ultimate mudline bearing capacity at this location is 2500 pounds per square foot (psf). A safety factor of 2.0 is recommended in computing the allowable bearing capacity at the mudline.

I L L U S T R A T I O N S

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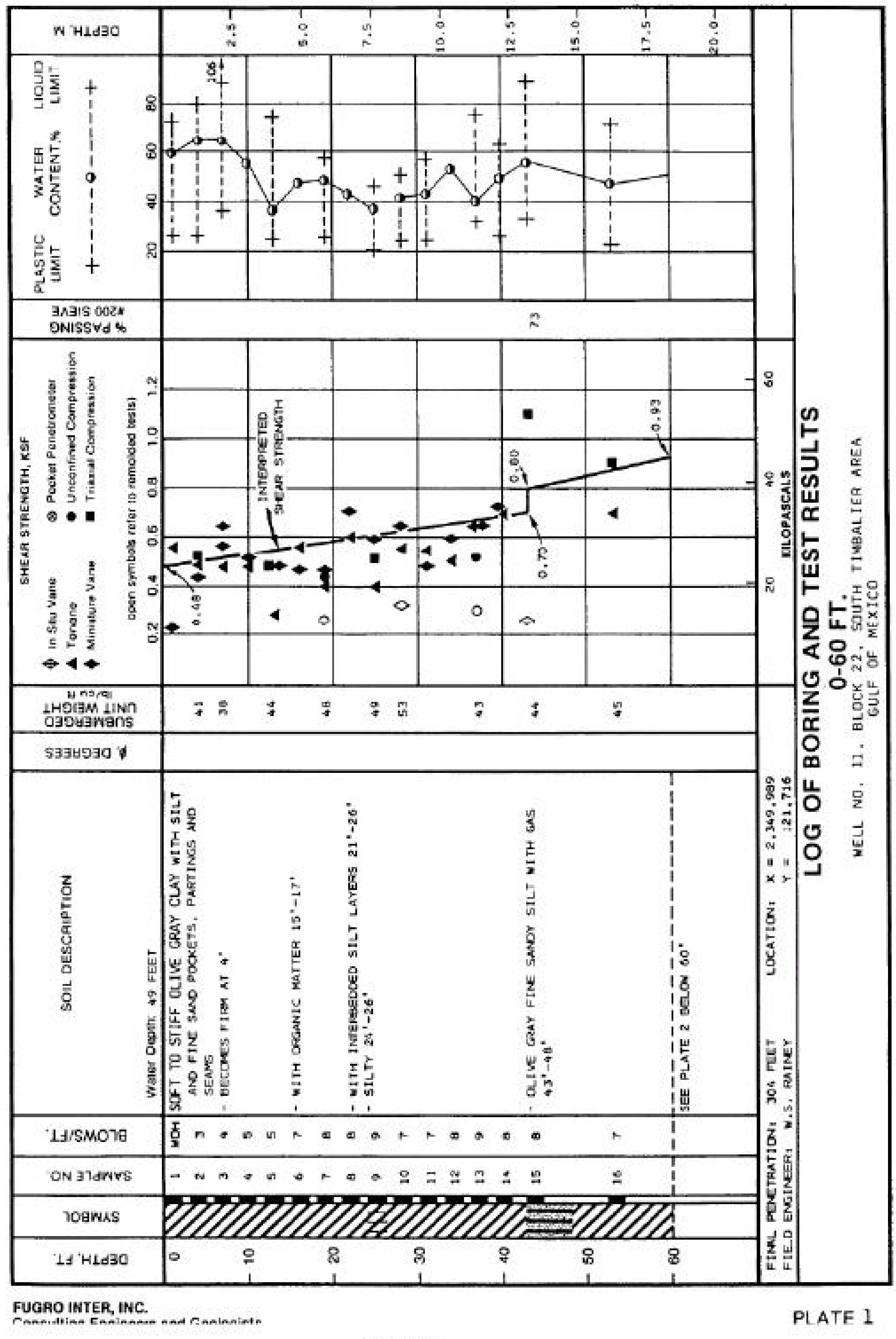
LOG OF BORING AND TEST RESULTS
0-60 FT.
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO
FUGRO INTER, INC.
PLATE 1
DEPTH, FT.
SYMBOL
SAMPLE NO.
BLOWS/FT.
SOIL DESCRIPTION
Water Depth: 49 FEET
SOFT TO STIFF OLIVE GRAY CLAY WITH SILT AND FINE SAND POCKETS, PARTINGS AND SEAMS
- BECOMES FIRM AT 4'
- WITH ORGANIC MATTER 15'-17'
- WITH INTERBEDDED SILT LAYERS 21'-26'
- SILTY 24'-26'
- OLIVE GRAY FINE SANDY SILT WITH GAS 43'-48'
SEE PLATE 2 BELOW 60'
FINAL PENETRATION: 304 FEET
FIELD ENGINEER: W.S. RAINEY
LOCATION: X = 2,349,989 Y = 121,716
ϕ DEGREES
SUBMERGED UNIT WEIGHT
SHEAR STRENGTH, KSF
In Situ Vane
Torvane
Miniature Vane
Pocket Penetrometer
Unconfined Compression
Triaxial Compression
open symbols refer to remolded tests
INTERPRETED SHEAR STRENGTH
KILOPASCALS
% PASSING #200 SIEVE
PLASTIC LIMIT
WATER CONTENT, %
LIQUID LIMIT
DEPTH, M

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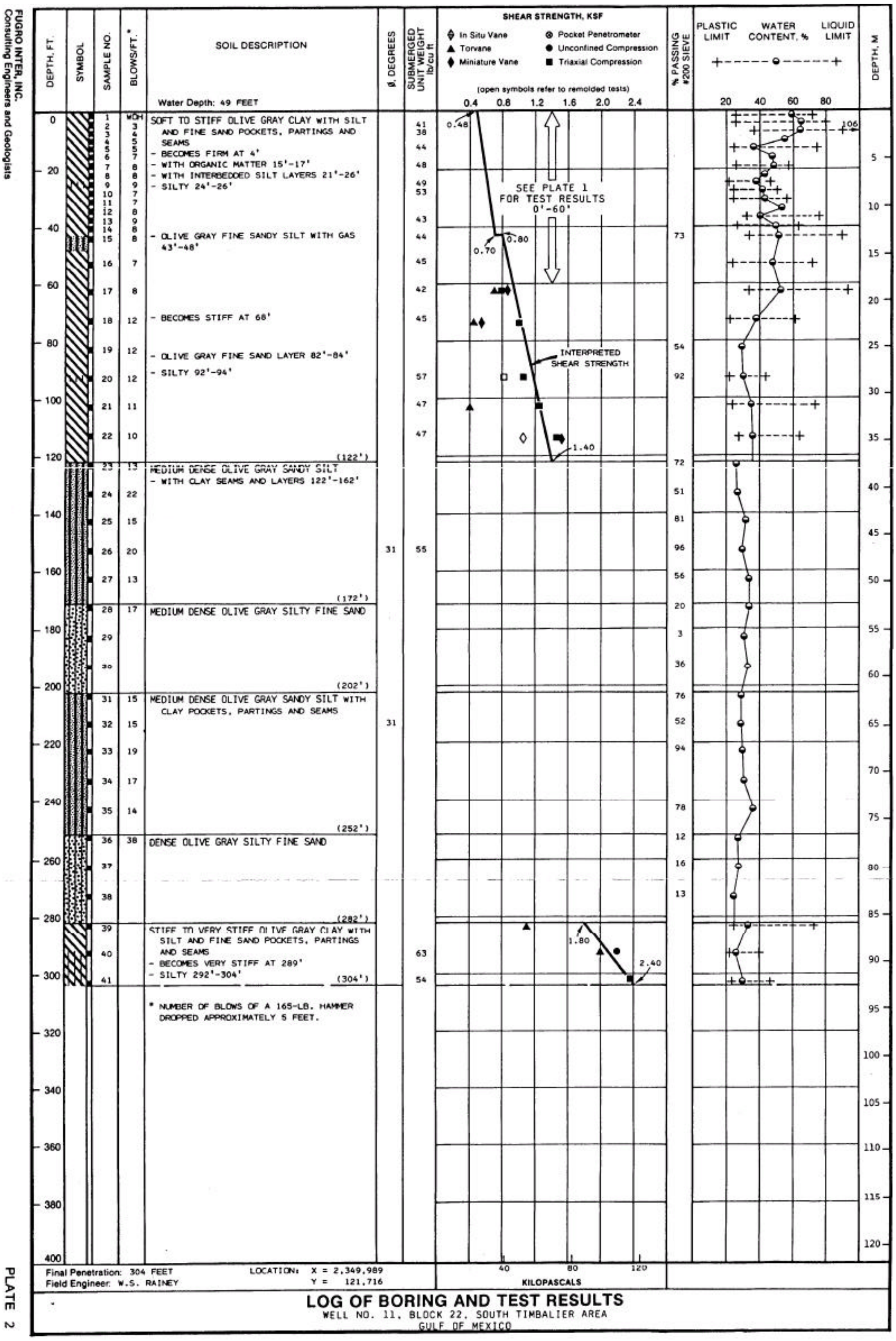
FUGRO INTER, INC.
Consulting Engineers and Geologists
DEPTH, FT.
SYMBOL
SAMPLE NO.
BLOWS/FT.*
SOIL DESCRIPTION
Water Depth: 49 FEET
SOFT TO STIFF OLIVE GRAY CLAY WITH SILT AND FINE SAND POCKETS, PARTINGS AND SEAMS
- BECOMES FIRM AT 4'
- WITH ORGANIC MATTER 15'-17'
- WITH INTERBEDDED SILT LAYERS 21'-26'
- SILTY 24'-26'
- OLIVE GRAY FINE SANDY SILT WITH GAS 43'-48'
- BECOMES STIFF AT 68'
- OLIVE GRAY FINE SAND LAYER 82'-84'
- SILTY 92'-94'
(122')
MEDIUM DENSE OLIVE GRAY SANDY SILT
- WITH CLAY SEAMS AND LAYERS 122'-162'
(172')
MEDIUM DENSE OLIVE GRAY SILTY FINE SAND
(202')
MEDIUM DENSE OLIVE GRAY SANDY SILT WITH CLAY POCKETS, PARTINGS AND SEAMS
(252')
DENSE OLIVE GRAY SILTY FINE SAND
(282')
STIFF TO VERY STIFF OLIVE GRAY CLAY WITH SILT AND FINE SAND POCKETS, PARTINGS AND SEAMS
- BECOMES VERY STIFF AT 289'
- SILTY 292'-304'
(304')
* NUMBER OF BLOWS OF A 165-LB. HAMMER DROPPED APPROXIMATELY 5 FEET.
Ø, DEGREES
SUBMERGED UNIT WEIGHT lb/cu ft
SHEAR STRENGTH, KSF
In Situ Vane
Torvane
Miniature Vane
Pocket Penetrometer
Unconfined Compression
Triaxial Compression
(open symbols refer to remolded tests)
SEE PLATE 1 FOR TEST RESULTS 0'-60'
INTERPRETED SHEAR STRENGTH
KILOPASCALS
% PASSING #200 SIEVE
PLASTIC LIMIT
WATER CONTENT, %
LIQUID LIMIT
DEPTH, M
Final Penetration: 304 FEET
Field Engineer: W.S. RAINEY
LOCATION: X = 2,349,989
Y = 121,716
LOG OF BORING AND TEST RESULTS
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO
PLATE 2

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KEY TO SOIL CLASSIFICATION AND SYMBOLS

SOIL TYPE
(Shown in Symbol Column)

SAMPLE TYPE
(Shown in Samples Column)

Predominant type shown heavy

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE GRAINED SOILS (Major Portion Retained on No. 200 Sieve)

Includes (1) clean gravels & sand described as fine, medium or coarse, depending on distribution of grain sizes & (2) silty or clayey gravels & sands (3) fine grained low plasticity soils (PI < 10) such as sandy silts. Condition is rated according to relative density, as determined by lab tests or estimated from resistance to sampler penetration.

Descriptive Term	Penetration Resistance*	Relative Density
Loose	0 – 10	0 to 40 %
Medium Dense	10 – 30	40 to 70 %
Dense	30 – 50	70 to 90 %
Very Dense	Over 50	90 to 100 %

**Blows/Ft., 140# hammer, 30" drop*

FINE GRAINED SOILS (Major Portion Passing No. 200 Sieve)

Includes (1) inorganic & organic silts & clays, (2) sandy, gravelly or silty clays, & (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings or by unconfined compression tests for soils with PI ≥ 10

Descriptive Term	Cohesive Shear Strength Tons/Sq. Ft.
Very Soft	Less Than 0.125
Soft	0.125 to 0.25
Firm	0.25 to 0.50
Stiff	0.50 to 1.00
Very Stiff	1.00 to 2.00
Hard	2.00 and Higher

NOTE: SLICKENSIDED AND FISSURED CLAY MAY HAVE LOWER UNCONFINED COMPRESSIVE STRENGTHS THAN SHOWN ABOVE, BECAUSE OF PLANES OF WEAKNESS OR SHRINKAGE CRACKS; CONSISTENCY RATINGS OF SUCH SOILS ARE BASED ON HAND PENETROMETER READINGS

TERMS CHARACTERIZING SOIL STRUCTURE

Parting:	paper thin in size
Seam:	1/8"–3" thick
Layer:	greater than 3"
Fissured:	containing shrinkage cracks, frequently filled with fine sand or silt; usually more or less vertical
Sensitive:	pertaining to cohesive soils that are subject to appreciable loss of strength when remolded
Interbedded:	composed of alternate layers of different soil types
Laminated:	composed of thin layers of varying color and texture
Calcareous:	containing appreciable quanities of calcium carbonate
Well Graded:	having wide range in grain sizes and substantial amounts of all intermediate particle sizes
Poorly Graded:	predominately of one grain size, or having a range of sizes with some intermediate size missing
Flocculated:	pertaining to cohesive soils that exhibit a loose knit or flakey structure
Slickensided:	having inclined planes of weakness that are slick and glossy in appearance

DEGREE OF SLICKENSIDED DEVELOPMENT

Slightly Slickensided:	slickensides present at intervals of 1'-2'; soil does not easily break along these planes
Moderately Slickensided:	slickensides spaced at intervals of 1'-2'; soil breaks easily along these planes
Extremely Slickensided:	continuous and interconnected slickensides spaced at intervals of 4"–12"; soil breaks along the slickensides into pieces 3"–6" in size
Intensely Slickensided:	slickensides spaced at intervals of less than 4", continuous in all directions; soil breaks down along planes into nodules 1/4"–2" in size

FUGRO INTER. INC.

PLATE 3

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SUMMARY OF FIELD ACTIVITIES
SOIL AND FOUNDATION INVESTIGATION
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

DATE	TIME FROM	TIME TO	DESCRIPTION OF ACTIVITY
12/19/83	23:00	24:00	Fugro Inter crew and equipment enroute to Martin Fuel Dock, Fourchon, Louisiana from Houston, Texas.
12/20/83	00:00	08:00	Enroute to Martin Fuel Dock, Fourchon, Louisiana.
	08:00	11:30	Standby, waiting for trucks with drilling equipment to arrive.
	11:30	17:00	Loading equipment. Welding equipment to deck of jack-up barge M/V WAYNE DICKENSON.
	17:00	17:30	Loading drilling mud at Baroid dock: 3 pallets zeogel; 160 bags loaded. 3 pallets barite; 120 bags loaded.
	17:30	19:00	M/V WAYNE DICKENSON enroute to Well No. 11 site, Block 22, South Timbalier Area.
	19:00	19:30	Jacking up on site.
	19:30	21:30	Awaiting final check by surveyors.
	21:30	24:00	Standing by to begin drilling. Position is x = 2,349,989, y = 121,716. (619 FWL, 2144 FSL)
12/21/84	00:00	01:00	Standing by.
	01:00	03:00	Rigging up to begin drilling.
	03:00	05:00	Maintenance on mud pump.
	05:00	06:00	Prepare to drill: Water depth = 48' with wireline; 50' with echo sounder; average = 49 feet.
	06:00	19:00	Drilling, sampling and testing. Termination depth = 304 feet.
	19:00	19:30	Rigging down.
	19:30	21:30	Transit to Martin Fuel Dock.
	21:30	23:00	Loading all equipment except drill rig onto truck for transit to Houston.
	23:00	24:00	Standby waiting on larger crane.
12/22/84	00:00	02:00	Loading drill rig onto truck.
	02:00	03:00	Unloading drilling mud at Baroid dock: 80 bags Zeogel returned. 75 bags weight (barite) returned.
	03:00	11:30	Fugro Inter crew and equipment enroute to Houston.

FUGRO INTER, INC.

PLATE 4

soil.max

Job No.

SUMMARY OF FIELD ACTIVITIES
LEG PENETRATION MONITORING
READING AND BATES RANDOLPH YOST
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

DATE	TIME FROM	TIME TO	DESCRIPTION OF ACTIVITY
12/30/83	05:32	06:15	Fugro Inter engineer V. Baglioni enroute to Houston Interncontinental Airport via Fugro vehicle.
	06:15	07:00	Parking Fugro vehicle and awaiting departure of flight to Lafayette, Louisiana.
	07:00	07:45	Traveling to Lafayette via commercial aircraft.
	07:45	08:30	Traveling to Tenneco office with Noble Denton surveyor Heinrich Nagel and Reading & Bates superintendent Sam Boutte via Reading & Bates vehicle and awaiting meeting.
	08:30	09:30	Meeting with J. Simon, H. Nagel and S. Boutte at Tenneco office.
	09:30	13:45	Traveling to Fourchon, Louisiana via Reading & Bates vehicle.
	13:45	15:00	H. Nagel and S. Boutte inspecting tow boats. Awaiting transportation to rig.
	15:00	15:10	Traveling to rig RANDOLPH YOST via helicopter. Rig on location at "C" Platform, Block 22, South Timbalier Area.
	15:10	24:00	Waiting onboard for rig to transit to new location.
12/31/83	00:00	24:00	Waiting for rig to transit to new location.
	11:45		Begin skidding in cantilever.
	16:00		Raising deep well.
	16:45		Begin jacking.
	17:15		Hooking up tow lines to tugs, begin pulling and jetting on legs.
01/01/84	00:00	00:50	Jetting legs free.
	00:50	07:20	Standing by for daylight to move rig.
	07:20	08:10	Jacking legs free of bottom.
	08:10	09:40	Under tow to Well No. 11, Block 22, South Timbalier Area, positioning on location.
	09:40	10:30	Position confirmation; location approval.
	10:30	10:53	Jacking up to 8 foot draft. Spud can tip penetration = 12 feet.
	10:53	12:00	Raising hull to clear water. Spud can tip penetration: port = 23 feet, bow = 22 feet, starboard = 23 feet. Initial leg load = 6640 kips.
	12:00	16:00	Jacking up to a 5-foot airgap. Preloading to 50% (approximately 5400 kips).

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PLATE 5

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Job No.

SUMMARY OF FIELD ACTIVITIES
LEG PENETRATION MONITORING
READING AND BATES RANDOLPH YOST
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

DATE	TIME FROM	TIME TO	DESCRIPTION OF ACTIVITY
01/01/84 (Cont'd.)	16:00	16:30	Monitoring preload. Spud can tip penetrations: port = 32 feet, bow = 24 feet, starboard = 27 feet.
	16:30	17:35	Continue preloading. At 6800 kips preload, additional penetration reduces airgap to 2 feet.
	17:35	18:10	Dumping most of preload. Jacking back up to 5-foot airgap. Spud can tip penetrations: bow = 29 feet, port = 36 feet, starboard = 32 feet.
	18:10	22:06	Continue preloading. Full preload of 10,817 kips applied. Leg load = 10,250 kips. V. Baglioni recommends holding preload 2 hours.
	22:06	23:06	Holding preload. Rig settles to 1 foot draft on stern. At 2250 hours, spud can tip penetrations: port = 42 feet, bow = 36 feet, starboard = 41 feet.
	23:06	24:00	Dumping preload. Jacking up to drilling airgap.
01/02/84	00:00	06:30	Awaiting transportation to shore.
	06:30	07:00	Bubbles observed near well site. Meeting to discuss situation. V. Baglioni suggests that bubbles are escaping from lower sand layer through previous soil boring hole. Decision to call in diver to check if air (gas?) is seeping from around spud cans. Noble Denton and Reading & Bates decide to skid cantilever in, jack down to minimum airgap and reapply preload to try to get additional penetration.
	07:00	11:00	Prepare for preloading.
	11:00	16:45	Reapply preload of 10,817 kips.
	12:30	14:30	Divers inspecting source of gas. Bubbles are coming from previous borehole. Spud can holes are observed to be open by divers.
	13:30	14:30	Safety meeting.
	16:45	17:45	Holding preload. Monitoring penetration. Final penetration = 37, 42 and 43 for the bow, starboard and port legs, respectively.
	17:45	18:15	Dumping preload.
	18:15	19:00	Jacking hull up to drilling airgap.
	19:00	24:00	Awaiting transportation to shore.

FUGRO INTER, INC.

PLATE 5a

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Job No.

SUMMARY OF FIELD ACTIVITIES
LEG PENETRATION MONITORING
READING AND BATES RANDOLPH YOST
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO

DATE	TIME FROM	TIME TO	DESCRIPTION OF ACTIVITY
01/03/84	00:00	07:30	Awaiting transportation to shore.
	07:30	07:40	Traveling to Fourchon Base via helicopter.
	07:40	11:50	Traveling to Lafayette via Reading & Bates vehicle.
	11:50	13:40	Awaiting departure of flight to Houston.
	13:40	14:30	Traveling to Houston Intercontinental Airport via commercial aircraft.
	14:30	15:45	Picking up Fugro company vehicle at Satellite Parking Lot and traveling to Fugro office.

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PLATE 5b

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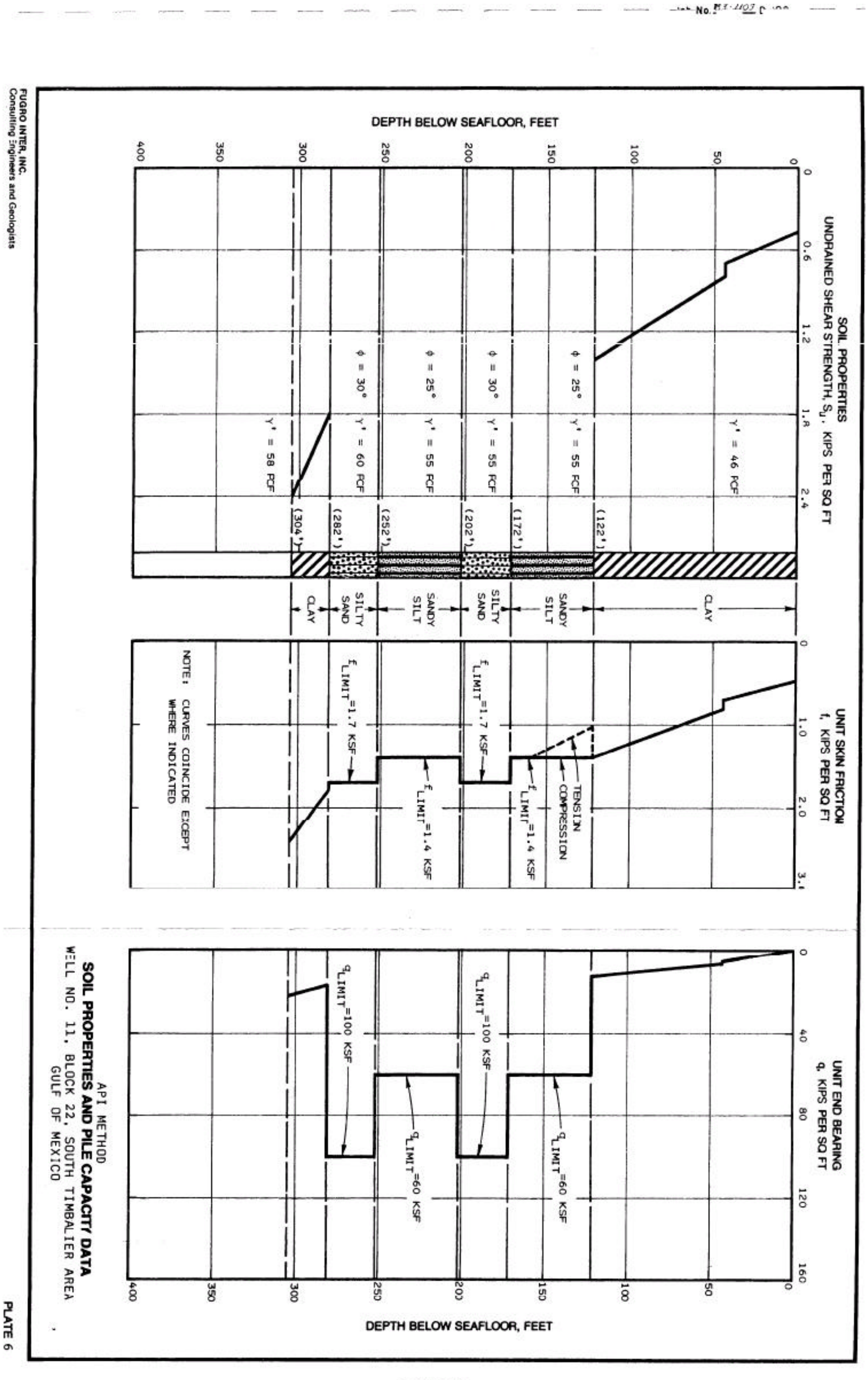
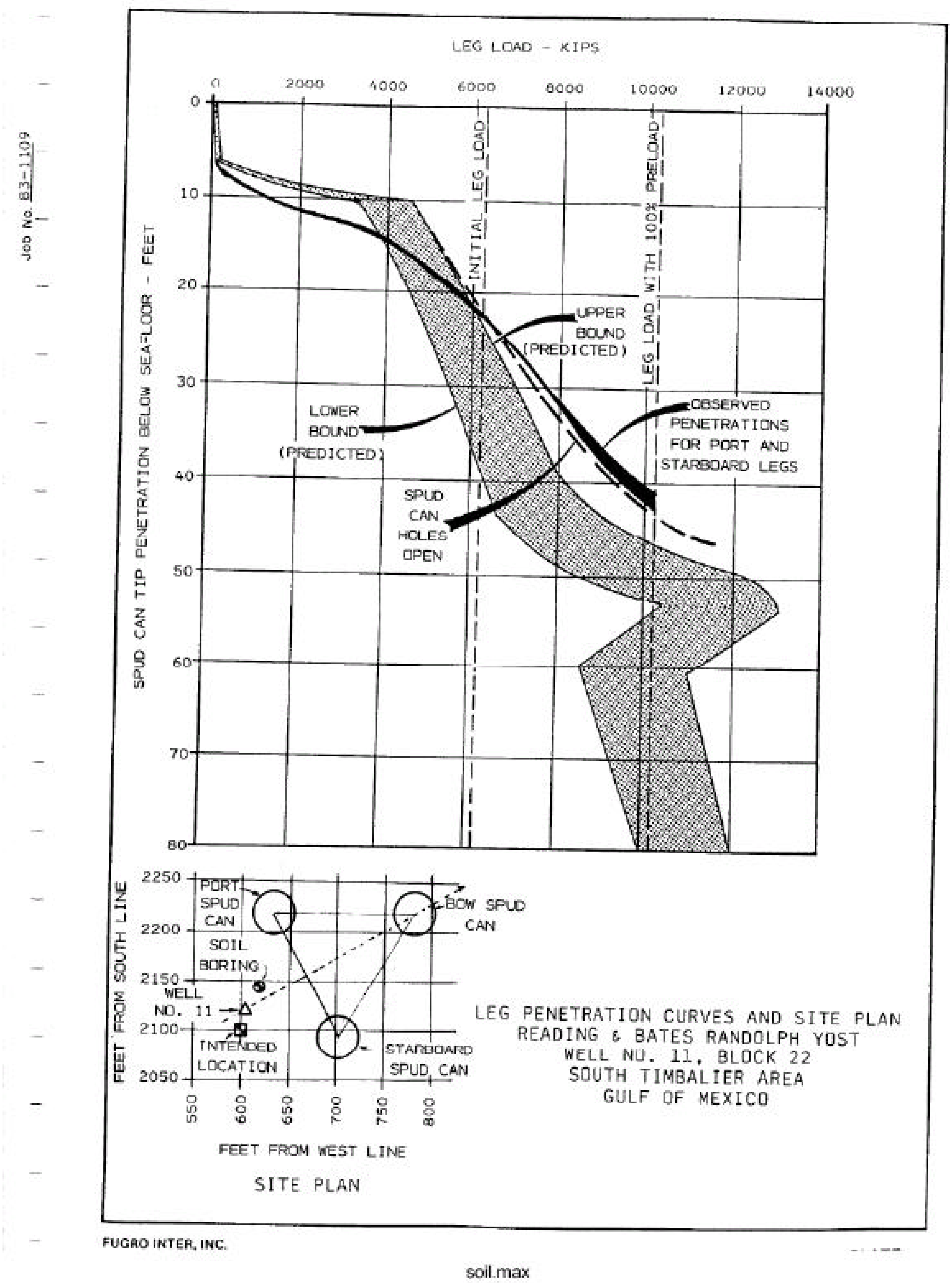
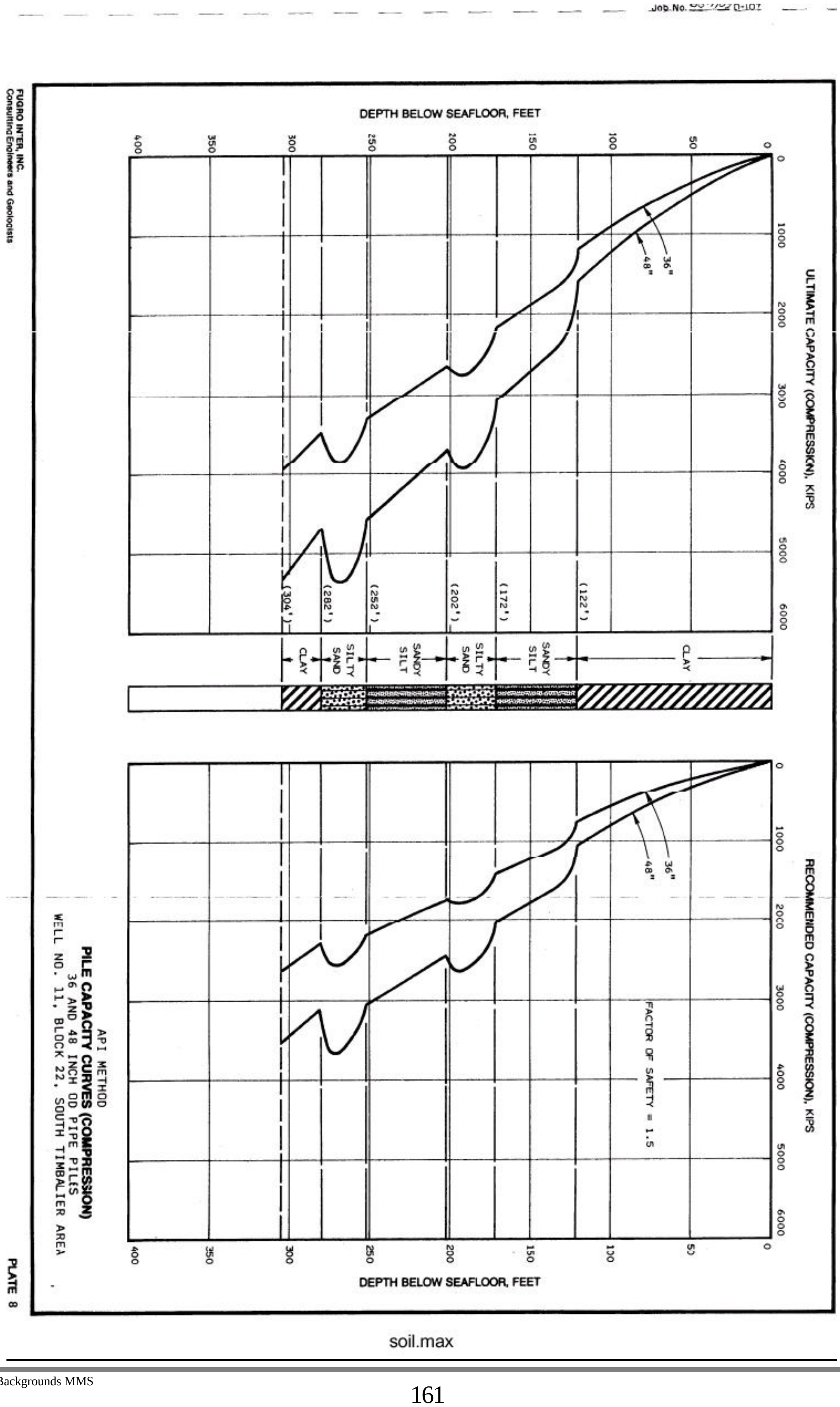

FUGRO INTER, INC.
Consulting Engineers and Geologists
DEPTH BELOW SEAFLOOR, FEET
SOIL PROPERTIES
UNDRAINED SHEAR STRENGTH, S_u, KIPS PER SQ FT
UNIT SKIN FRICTION
f, KIPS PER SQ FT
UNIT END BEARING
q, KIPS PER SQ FT
CLAY
SANDY SILT
SILTY SAND
NOTE: CURVES COINCIDE EXCEPT WHERE INDICATED
TENSION
COMPRESSION
API METHOD
SOIL PROPERTIES AND PILE CAPACITY DATA
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
GULF OF MEXICO
PLATE 6

soil.max


Job No. 83-1109
LEG LOAD - KIPS
0
2000
4000
6000
8000
10000
12000
14000
SPUD CAN TIP PENETRATION BELOW SEAFLOOR - FEET
10
20
30
40
50
60
70
80
INITIAL LEG LOAD
LEG LOAD WITH 100% PRELOAD
UPPER BOUND (PREDICTED)
LOWER BOUND (PREDICTED)
OBSERVED PENETRATIONS FOR PORT AND STARBOARD LEGS
SPUD CAN HOLES OPEN
FEET FROM SOUTH LINE
2250
2200
2150
2100
2050
PORT SPUD CAN
BOW SPUD CAN
SOIL BORING
WELL NO. 11
INTENDED LOCATION
STARBOARD SPUD CAN
550
600
650
700
750
800
FEET FROM WEST LINE
SITE PLAN
LEG PENETRATION CURVES AND SITE PLAN
READING & BATES RANDOLPH YOST
WELL NO. 11, BLOCK 22
SOUTH TIMBALIER AREA
GULF OF MEXICO
FUGRO INTER, INC.

soil.max


DEPTH BELOW SEAFLOOR, FEET
ULTIMATE CAPACITY (COMPRESSION), KIPS
36"
48"
(122')
(172')
(202')
(252')
(282')
(304')
CLAY
SANDY SILT
SILTY SAND
SANDY SILT
SILTY SAND
CLAY
RECOMMENDED CAPACITY (COMPRESSION), KIPS
FACTOR OF SAFETY = 1.5
DEPTH BELOW SEAFLOOR, FEET
API METHOD
PILE CAPACITY CURVES (COMPRESSION)
36 AND 48 INCH OD PIPE PILES
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
FUGRO INTER, INC.
Consulting Engineers and Geologists
PLATE 8

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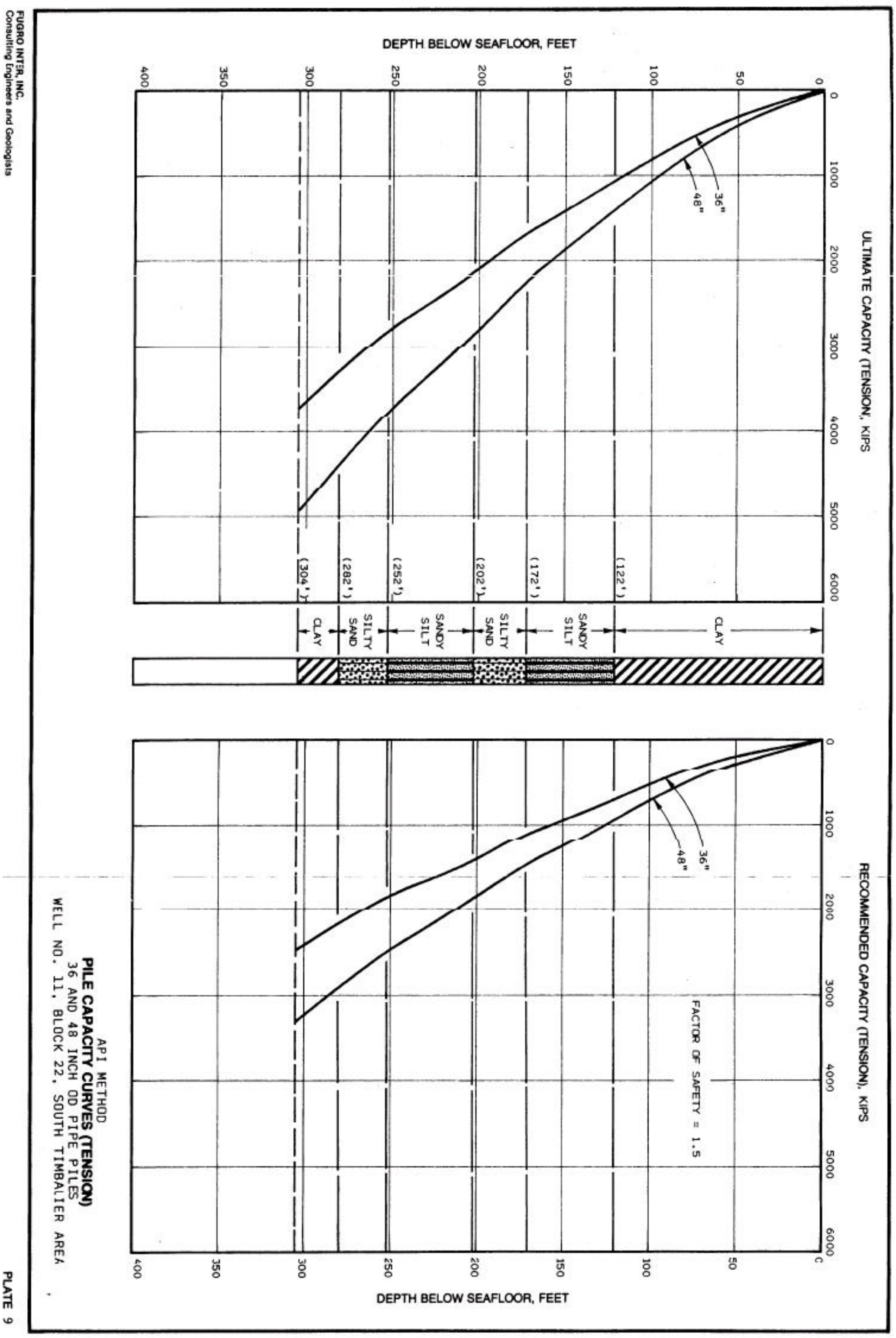
FUGRO INTER, INC.
Consulting Engineers and Geologists
DEPTH BELOW SEAFLOOR, FEET
ULTIMATE CAPACITY (TENSION), KIPS
RECOMMENDED CAPACITY (TENSION), KIPS
36"
48"
FACTOR OF SAFETY = 1.5
CLAY
SANDY SILT
SILTY SAND
SANDY SILT
SILTY SAND
CLAY
(122')
(172')
(202')
(252')
(282')
(304')
API METHOD
PILE CAPACITY CURVES (TENSION)
36 AND 48 INCH OD PIPE PILES
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA
PLATE 9

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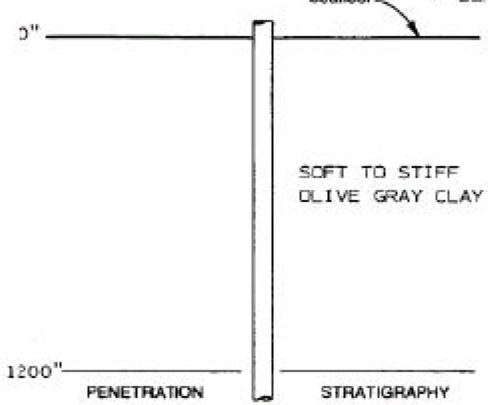
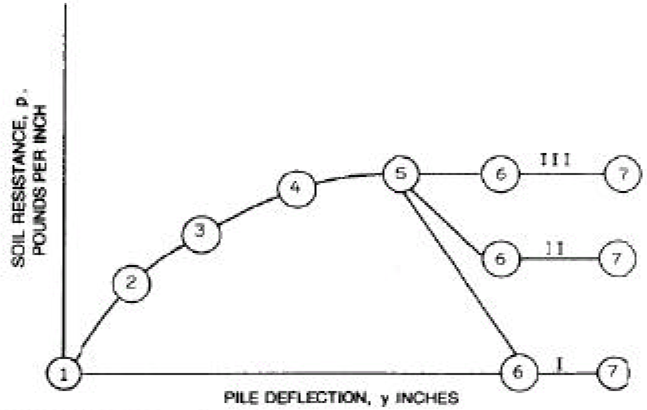
JOB NO. ______ C-103

PENETRATION IN INCHES	TYPICAL CURVE	COORDINATES OF CURVE POINTS															
		y_1	p_1	y_2	p_2	y_3	p_3	y_4	p_4	y_5	p_5	y_6	p_6	y_7	p_7	y_8	p_8
0	I	0	0	0.11	83	0.32	119	1.08	180	3.24	259	16.20	0	36	0		
36	II	0	0	0.11	108	0.32	154	1.08	234	3.24	337	16.20	44	36	44		
72	II	0	0	0.11	133	0.32	191	1.08	290	3.24	417	16.20	107	36	107		
120	II	0	0	0.11	169	0.32	242	1.08	367	3.24	529	16.20	223	36	223		
180	II	0	0	0.11	216	0.32	310	1.08	469	3.24	675	16.20	421	36	421		
*294	III	0	0	0.11	311	0.32	447	1.08	677	3.24	975	16.20	975	36	975		
300	III	0	0	0.11	315	0.32	451	1.08	684	3.24	985	16.20	985	36	985		
516	III	0	0	0.11	362	0.32	520	1.08	788	3.24	1134	16.20	1134	36	1134		
516	III	0	0	0.11	414	0.32	594	1.08	900	3.24	1296	16.20	1296	36	1296		
720	III	0	0	0.11	476	0.32	683	1.08	1035	3.24	1490	16.20	1490	36	1490		
720	III	0	0	0.14	476	0.41	683	1.35	1035	4.05	1490	20.25	1490	36	1490		
960	III	0	0	0.14	559	0.41	802	1.35	1215	4.05	1750	20.25	1750	36	1750		
1200	III	0	0	0.14	642	0.41	921	1.35	1395	4.05	2009	20.25	2009	36	2009		

* DEPTH OF FULL LATERAL CONFINEMENT





SOIL RESISTANCE–PILE DEFLECTION (p–y) DATA
36-INCH OD PIPE PILE
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA

FUGRO INTER, INC.

PLATE 1?

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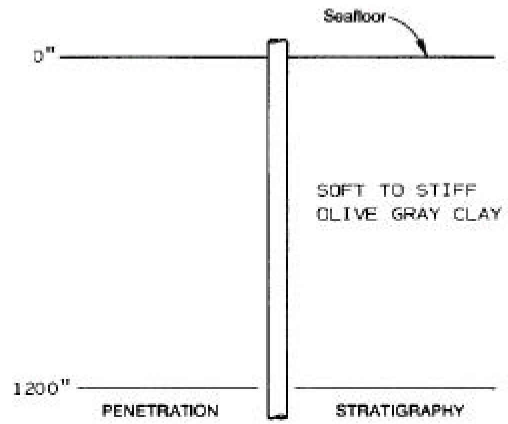
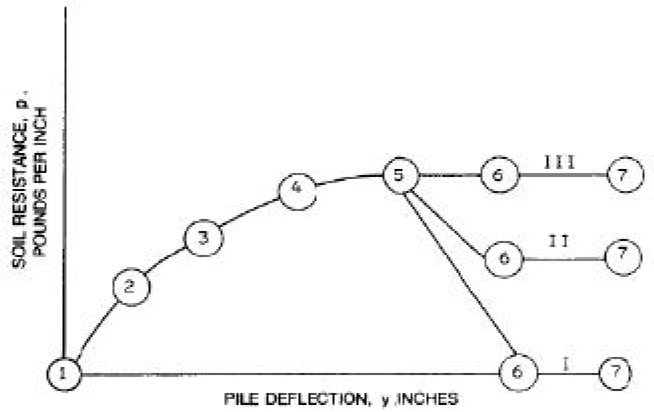
JOB NO. ______ C-103

PENETRATION IN INCHES	TYPICAL CURVE	COORDINATES OF CURVE POINTS															
		y_1	p_1	y_2	p_2	y_3	p_3	y_4	p_4	y_5	p_5	y_6	p_6	y_7	p_7	y_8	p_8
0	I	0	0	0.14	110	0.43	158	1.44	240	4.32	346	21.60	0	48	0		
48	II	0	0	0.14	148	0.43	213	1.44	323	4.32	465	21.60	67	48	67		
96	II	0	0	0.14	188	0.43	270	1.44	409	4.32	588	21.60	167	48	167		
180	II	0	0	0.14	261	0.43	374	1.44	567	4.32	817	21.60	424	48	424		
300	II	0	0	0.14	374	0.43	536	1.44	812	4.32	1170	21.60	978	48	978		
*360	III	0	0	0.14	434	0.43	622	1.44	943	4.32	1357	21.60	1357	48	1357		
516	III	0	0	0.14	483	0.43	693	1.44	1050	4.32	1512	21.60	1512	48	1512		
516	III	0	0	0.14	552	0.43	792	1.44	1200	4.32	1728	21.60	1728	48	1728		
720	III	0	0	0.14	635	0.43	911	1.44	1380	4.32	1987	21.60	1987	48	1987		
720	III	0	0	0.18	635	0.54	911	1.80	1380	5.40	1987	27.00	1987	48	1987		
960	III	0	0	0.18	745	0.54	1069	1.80	1620	5.40	2333	27.00	2333	48	2333		
1200	III	0	0	0.18	856	0.54	1228	1.80	1860	5.40	2678	27.00	2678	48	2678		

* DEPTH OF FULL LATERAL CONFINEMENT





SOIL RESISTANCE–PILE DEFLECTION (p–y) DATA
48-INCH OD PIPE PILE
WELL NO. 11, BLOCK 22, SOUTH TIMBALIER AREA

FUGRO INTER, INC.

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APPENDIX A

LABORATORY AND FIELD TESTS

FUGRO

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APPENDIX A

LABORATORY AND FIELD TESTS

CONTENTS

Fugro

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CLASSIFICATION TESTS

Moisture Content and Plasticity

Field classification and uniformity of strength are verified by natural moisture content and liquid and plastic limit tests performed in accordance with ASTM Procedures D2216-80, D423-66, and D424-59. The liquid limit represents the moisture content of the soil at the time of deposition when the soil is in a liquid condition, and the plastic limit is the moisture content at which the soil behaves as a semi-solid. Soil is plastic at moisture contents between the liquid and plastic limits.

The results of moisture content and plasticity tests performed are plotted on the boring logs, and are tabulated in the Summary of Test Results following the text of this Appendix.

Grain Size Analysis

Grain size analyses are performed on representative samples of granular soils in accordance with ASTM Procedure D422-63 and D1140-54. The selection of angle of friction, ϕ, for determination of engineering parameters is based upon grain size distributions. Results of these tests are presented as gradation curves following the text of this Appendix.

STRENGTH TESTS

Miniature Vane

This test is usually performed in the field on a cohesive sample prior to its removal from the sampling tube. Any disturbed soil in the bottom of the tube is removed, and a small 4-bladed vane is inserted into the undisturbed soil. Torque is applied to the vane through a calibrated coil spring activated by an electric motor, causing the vane to rotate slowly until soil shear failure occurs. The shear strength of the sample is computed from the observed angular displacement of the calibrated spring. The cohesive sample is sometimes remolded and tested in the same manner as the undisturbed sample. Undisturbed values are shown by the solid symbol and remolded values by the open symbol in the strength graph on the boring log. These values are tabulated in the Summary of Test Results in this Appendix.

Torvane

Shear strength of cohesive samples is also estimated in the field using a small hand-operated device known as a Torvane. This device consists of a metal disk with thin radial vanes projecting from one face and a torsional spring attached to the other face. The disk is pressed against the flat surface of an undisturbed specimen until the vane is fully embedded. The disk is then rotated until the soil enclosed within the vanes is sheared from the sample. The torsional spring is calibrated to indicate directly the shear strength of the soil. Results of Torvane tests are plotted on the boring log and are tabulated in the Summary of Test Results.

Unconfined Compression Test

In an unconfined compression test, a laterally unsupported cylindrical soil specimen is loaded axially to failure at a constant rate of strain.

Axial load is measured by a calibrated proving ring and sample deformation is measured by a dial gauge. Cohesive shear strength is computed as one-half of the observed compressive strength of the specimen. Samples were tested in the manner described in ASTM Procedure D2166-66. Shear strengths determined from the unconfined compression tests are plotted on the boring log and are tabulated in the Summary of Test Results.

This test is the simplest and quickest laboratory method commonly used to measure the shear strength of a cohesive soil. This test is believed to better represent the strength for firm to stiff clays more closely than results of miniature vane tests in the same material.

Triaxial Compression Test

Unconsolidated-Undrained

In this test, commonly designated as the quick or "Q" test, the soil specimen is enclosed in a thin rubber membrane and is subjected to a confining pressure approximately equal to the overburden pressure at the sample depth. The sample is not allowed to consolidate under this confining pressure. The specimen is then loaded axially to failure at a constant rate of strain without allowing any drainage from the sample. The test procedure generally followed is that given in ASTM D2850-70. Shear strengths obtained by this procedure are plotted on the boring log and are tabulated on the Summary of Test Results.

This test provides an alternative to the unconfined compression test for very soft to soft soils that will not form an unsupported cylinder in the unconfined test. The application of lateral pressure together with enclosure in a rubber membrane supports the soil specimen. Results of the test provide additional data for evaluation of shear strength and strain data for lateral soil resistance-pile deflection (p-y) curves.

Consolidated-Drained

This triaxial test, designated as the slow or "S" test, is normally performed on reconstituted samples of cohesionless strata. The soil specimen is placed in a rubber membrane and consolidated at an appropriate confining pressure; sample drainage or volume change is permitted under this ambient pressure. Axial loading is then applied at a sufficiently slow constant strain rate to permit sample drainage during the shearing phase. For two or more specimens subjected to diffferent values of confining pressure, a plot of the results in accordance with the Mohr criterion of shearing failure will define the angle of friction, ϕ , or strength increase with pressure, and cohesive shear strength , c, at zero confining pressure.

Multiple-Stage

Multiple-stage triaxial tests are normally performed by the consolidated-undrained or consolidated-drained procedure on reconstituted samples of cohesionless soil. In this test, the soil specimen is placed in a rubber membrane and the single specimen subjected to three different values of confining pressure. Generally, confining pressures correspond to one-half, one, and one and one-half the computed overburden pressure. Axial loading is then applied to a point of incipient failure and then reduced to zero prior to an increase in confining pressure. The increase in strength as a function of confining pressure, ϕ, or angle of shear and the cohesive shear strength, c, at zero confining pressure are then defined by a plot of the test results in accordance with the Mohr criterion of shearing failure. The results are shown graphically in this Appendix.

A P P E N D I X   A

LABORATORY AND FIELD TESTS

APPENDIX ILLUSTRATIONS

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SAMPLE NO.	DEPTH, FT	BLOWS/FOOT	CLASSIFICATION TESTS: LIQUID LIMIT	CLASSIFICATION TESTS: PLASTIC LIMIT	CLASSIFICATION TESTS: WATER CONTENT, %	CLASSIFICATION TESTS: SUBMERGED UNIT WEIGHT lb/cu ft	CLASSIFICATION TESTS: % PASSING # 200 SIEVE	SHEAR STRENGTH, KSF: PENETROMETER	SHEAR STRENGTH, KSF: TORVANE	SHEAR STRENGTH, KSF: MINIATURE VANE UNDISTURBED	SHEAR STRENGTH, KSF: MINIATURE VANE REMOLDED	SHEAR STRENGTH, KSF: UNCONFINED COMPRESSION UNDISTURBED	SHEAR STRENGTH, KSF: UNCONFINED COMPRESSION REMOLDED	SHEAR STRENGTH, KSF: TRIAXIAL COMPRESSION UNCONSOLIDATED UNDRAINED UNDISTURBED	SHEAR STRENGTH, KSF: TRIAXIAL COMPRESSION UNCONSOLIDATED UNDRAINED REMOLDED	SHEAR STRENGTH, KSF: TRIAXIAL COMPRESSION CONSOLIDATED UNDRAINED	ø, DEGREES
1	1	WOH	72	26	59				0.56	0.22							
2	4	3	79	26	65	41			0.48	0.43				0.52			
3	7	4	106	36	64	38			0.48	0.56/0.64							
4	10	5			55				0.48	0.51							
5	13	5	74	24	36	44			0.28	0.48				0.48			
6	16	7			47				0.56	0.46							
7	19	8	57	25	48	48			0.40	0.46		0.44	0.26				
8	22	8			43				0.60	0.70							
9	25	9	46	21	37	49			0.40	0.59				0.51			
10	28	7	50	24	41	53			0.55	0.64	0.32						
11	31	7	56	24	43				0.55	0.40							
12	34	8			53				0.50	0.59							
13	37	9	75	32	40	43			0.64	0.64		0.56	0.30				
14	40	8	63	26	49				0.70	0.72							
15	43	8	89	33	56	44	73				0.26			1.10			
16	53	7	71	23	47	45			0.70					0.90			
17	63	8	93	33	52	42			0.70	0.86				0.79			
18	73	12	61	22	38	45			0.44	0.54				1.01			
19	83	12			29		54										
20	93	12	43	21	30	57	92							1.05	0.81		
21	103	11	73	24	35	47			0.40					1.25			
22	113	10	64	28	36	47				1.52	1.04			1.46			
23	123	13			26		72										
24	133	22			27		51										
25	143	15			32		81										
26	153	20			30	55	96										31
27	163	13			34		56										
28	173	17			34		20										
29	183				31		3										
30	193				33		36										
31	203	15			29		76										
32	213	15			29		52										31
33	223	19			30		94										
34	233	17			31												
35	243	14			36		78										
36	253	38			27		12										
37	263				27		16										
38	273				25		13										
39	283		73	25	33				1.10								
40	293		40	22	26	63			2.00			2.20					
41	303		47	24	30	54								2.38			

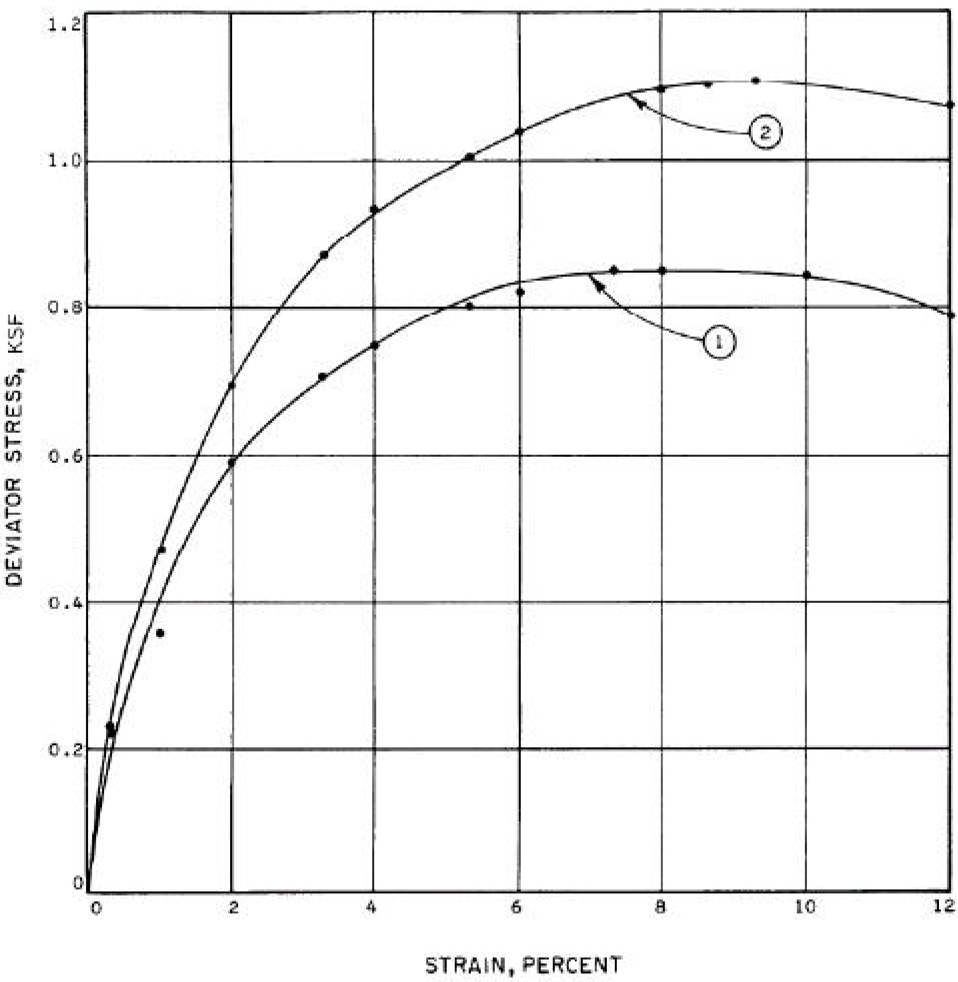
SUMMARY OF TEST RESULTS

FUGRO INTER, INC.

PLATE A-1

soil.max

Job No 83-1129



CURVE NO.	SAMPLE NO.	DEPTH, FT.	MATERIAL
1	7	18	SOFT OLIVE GRAY CLAY WITH SILT PARTINGS AND POCKETS
2	13	36	FIRM OLIVE GRAY CLAY WITH SILT PARTINGS

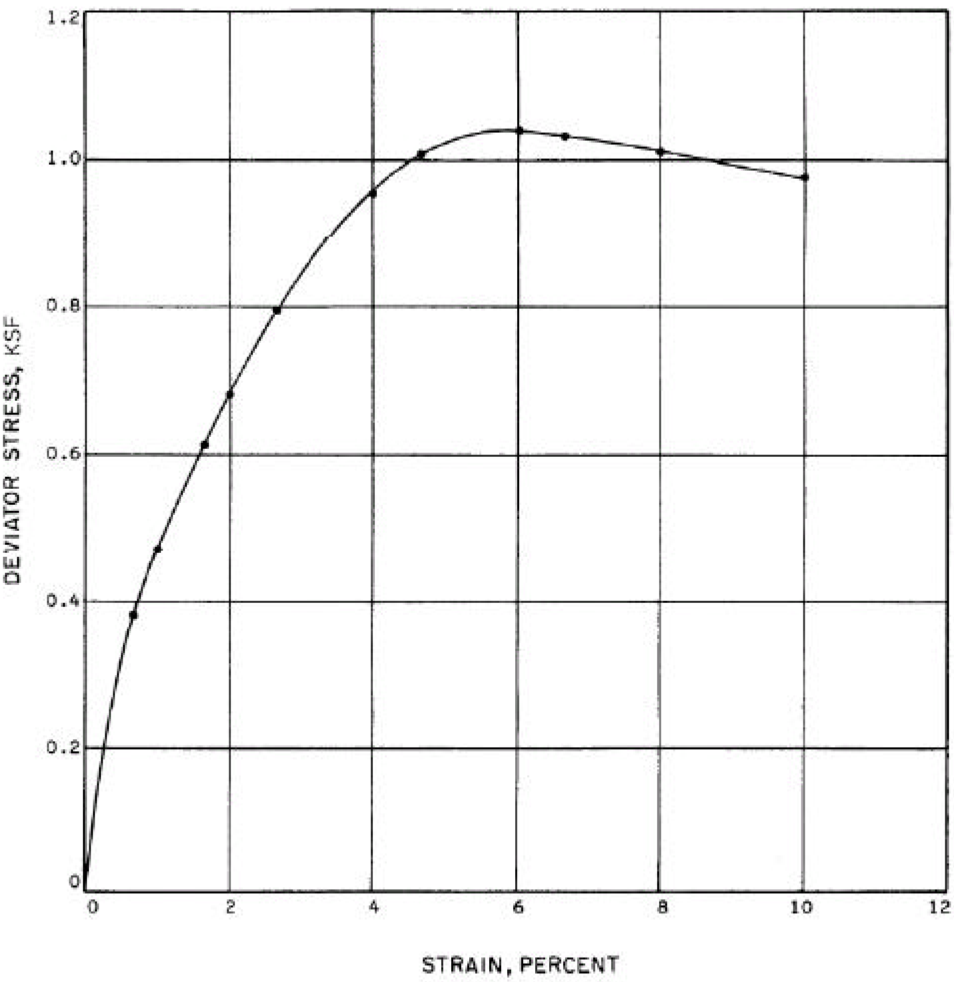
STRESS-STRAIN CURVES
UNCONFINED COMPRESSION TEST

FUGRO
Consulting Engineers and Geologists

PLATE B-2

soil.max

JOB No. 83-1109



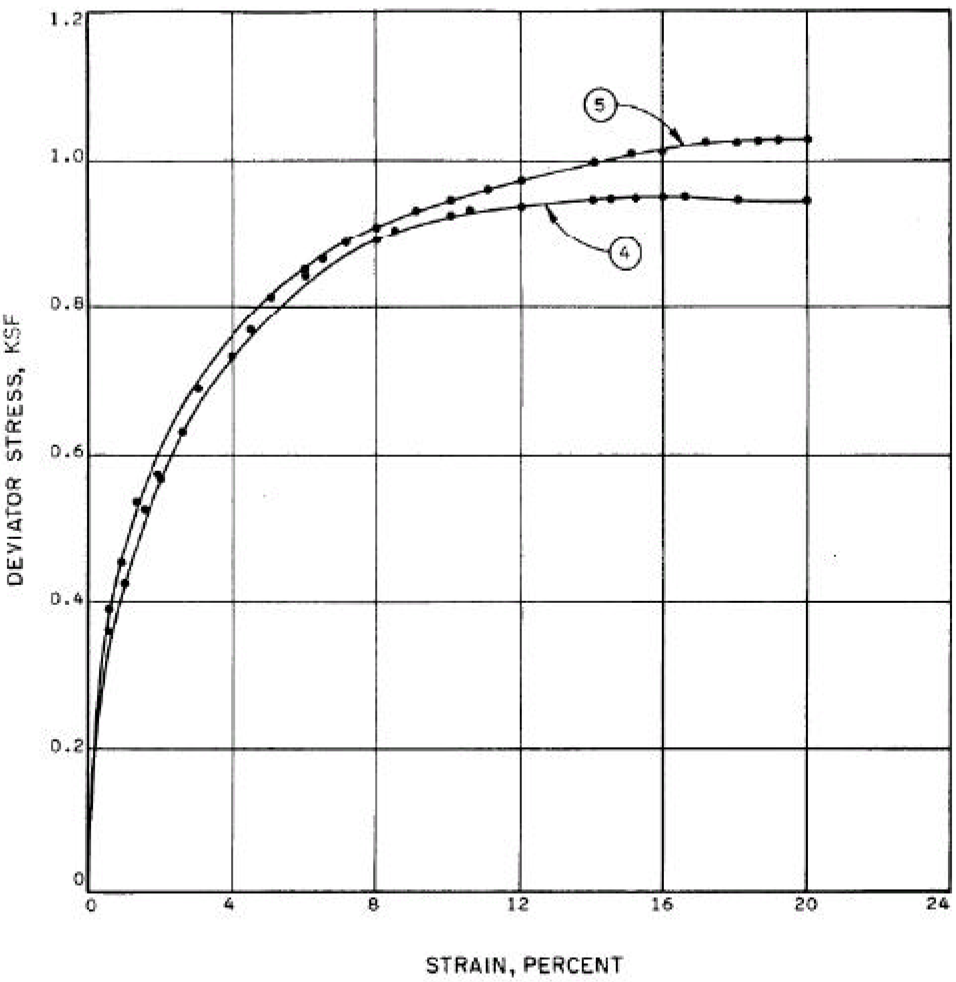
CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
3	2	3.0	0.72	FIRM OLIVE GRAY CLAY WITH SILT PARTINGS

STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-3

soil.max



CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
4	5	12.5	1.44	SOFT OLIVE GRAY CLAY WITH SILT SEAMS AND SAND POCKETS
5	9	24.0	2.60	FIRM OLIVE GRAY SILTY CLAY WITH SAND POCKETS AND PARTINGS

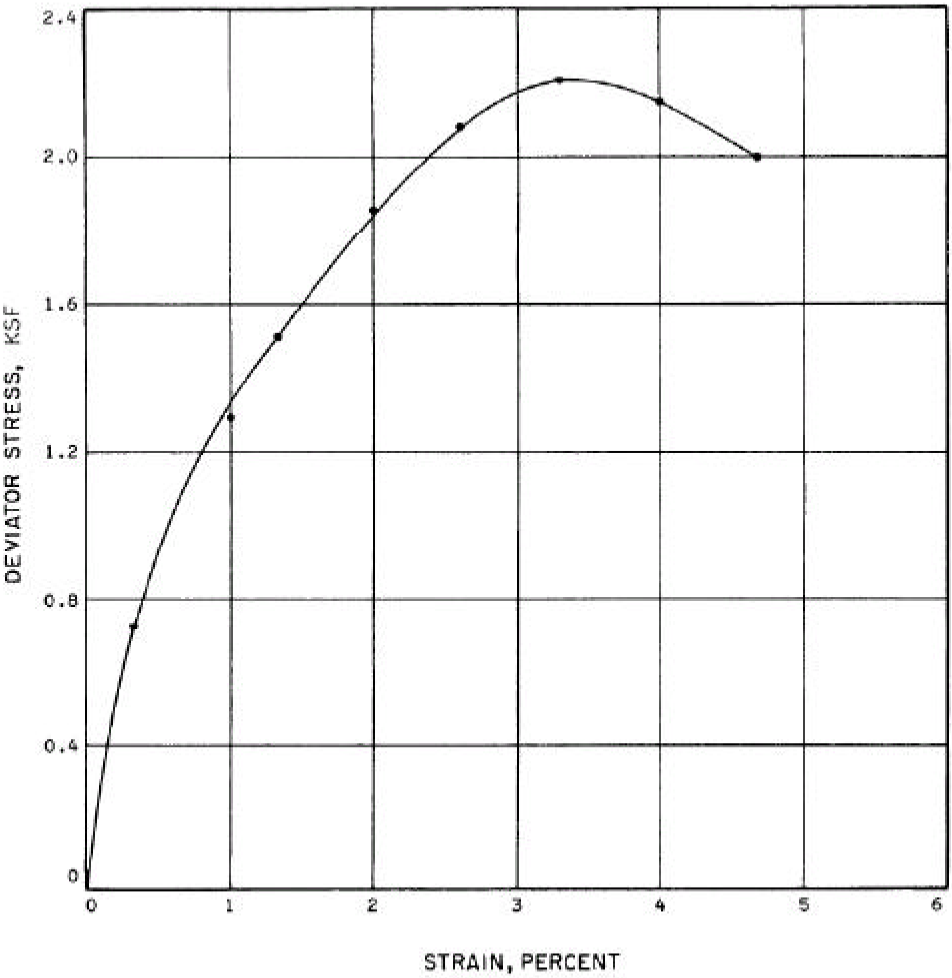
STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-4

soil.max

JOB No 83-1109



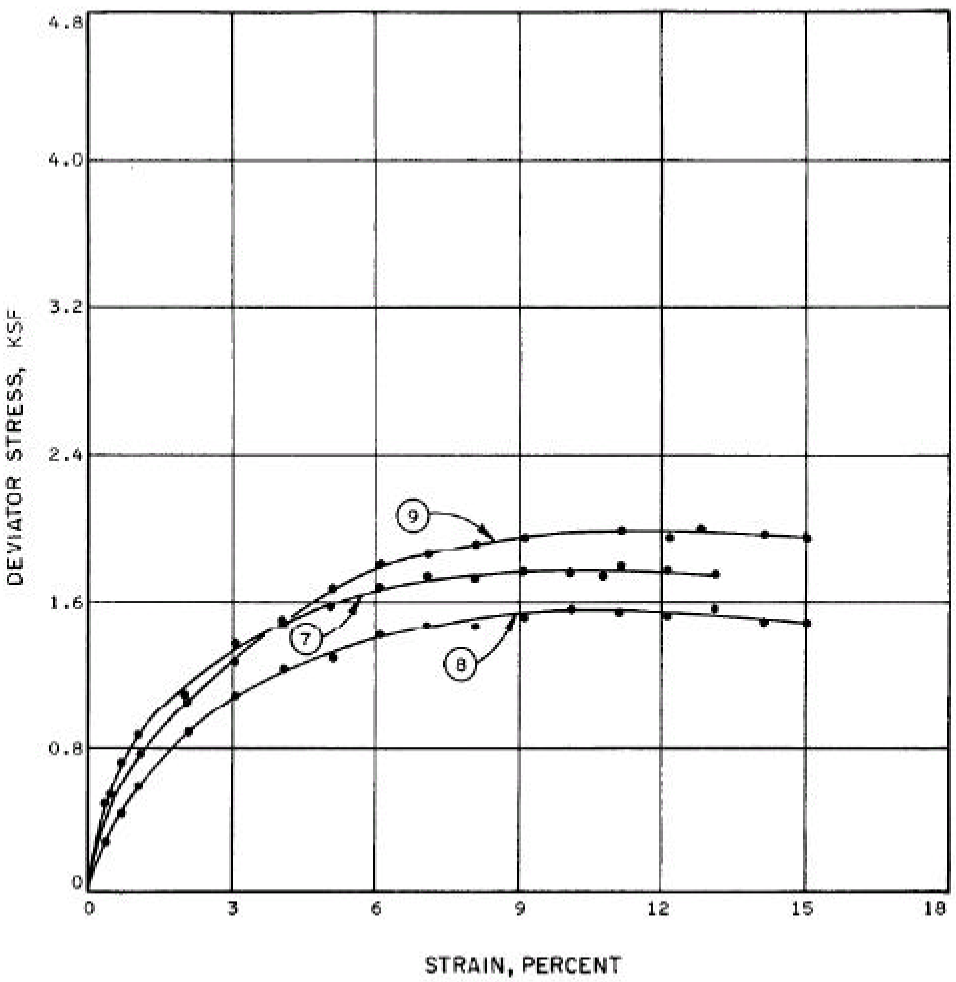
CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
6	15	42.5	4.32	STIFF OLIVE GRAY CLAY WITH SILT POCKETS

STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-5

soil.max



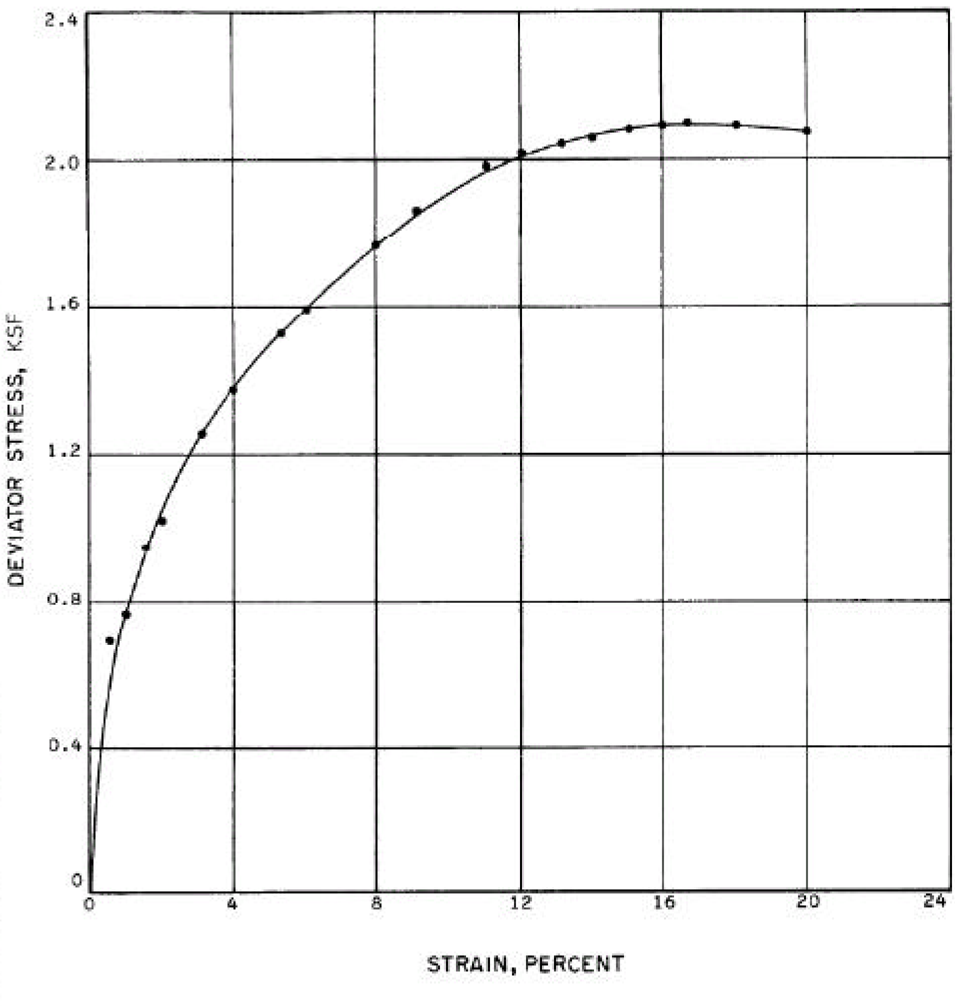
CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
7	16	53	2.88	FIRM OLIVE GRAY CLAY WITH SILT PARTINGS, FLOCCULATED
8	17	67.5	3.60	FIRM OLIVE GRAY CLAY WITH SAND POCKETS, FLOCCULATED
9	18	73.0	3.88	STIFF OLIVE GRAY CLAY, FLOCCU-LATED

STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-6

soil.max



CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
10	20	92.5	9.80	STIFF OLIVE GRAY SILTY CLAY WITH SAND SEAMS AND PARTINGS

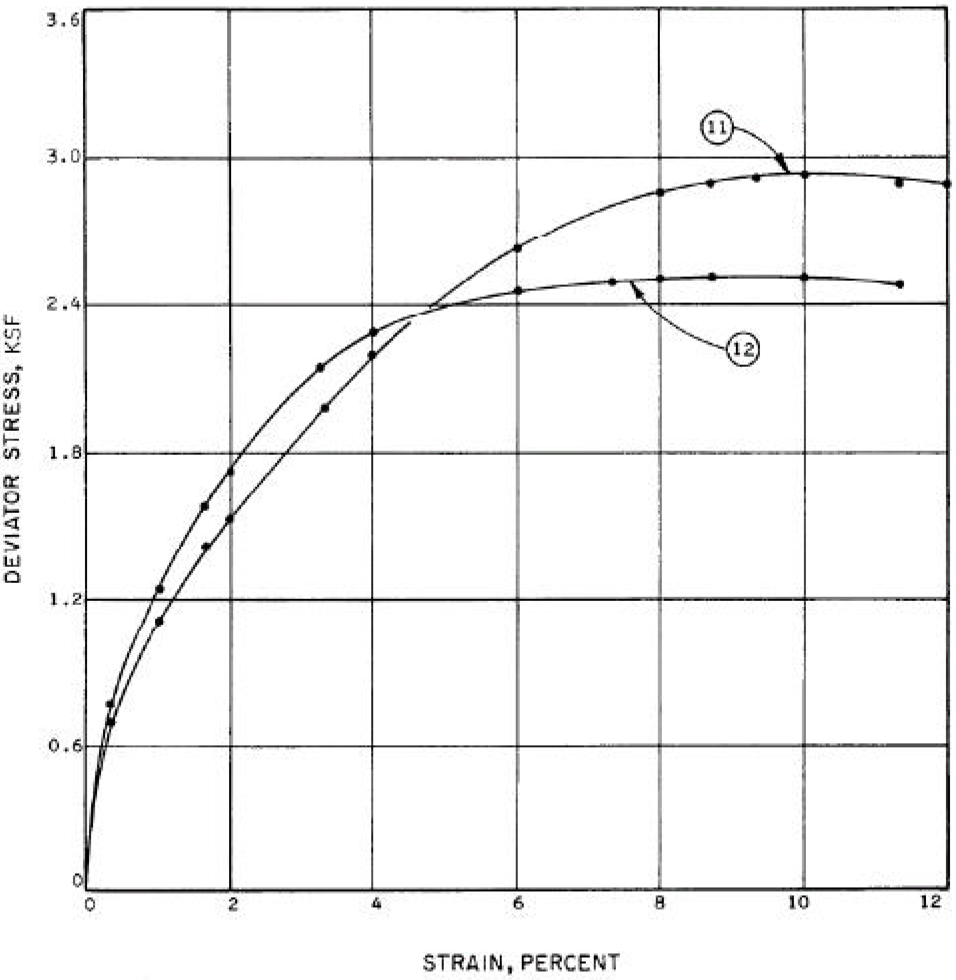
STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-7

soil.max

JOB No. 83-1109



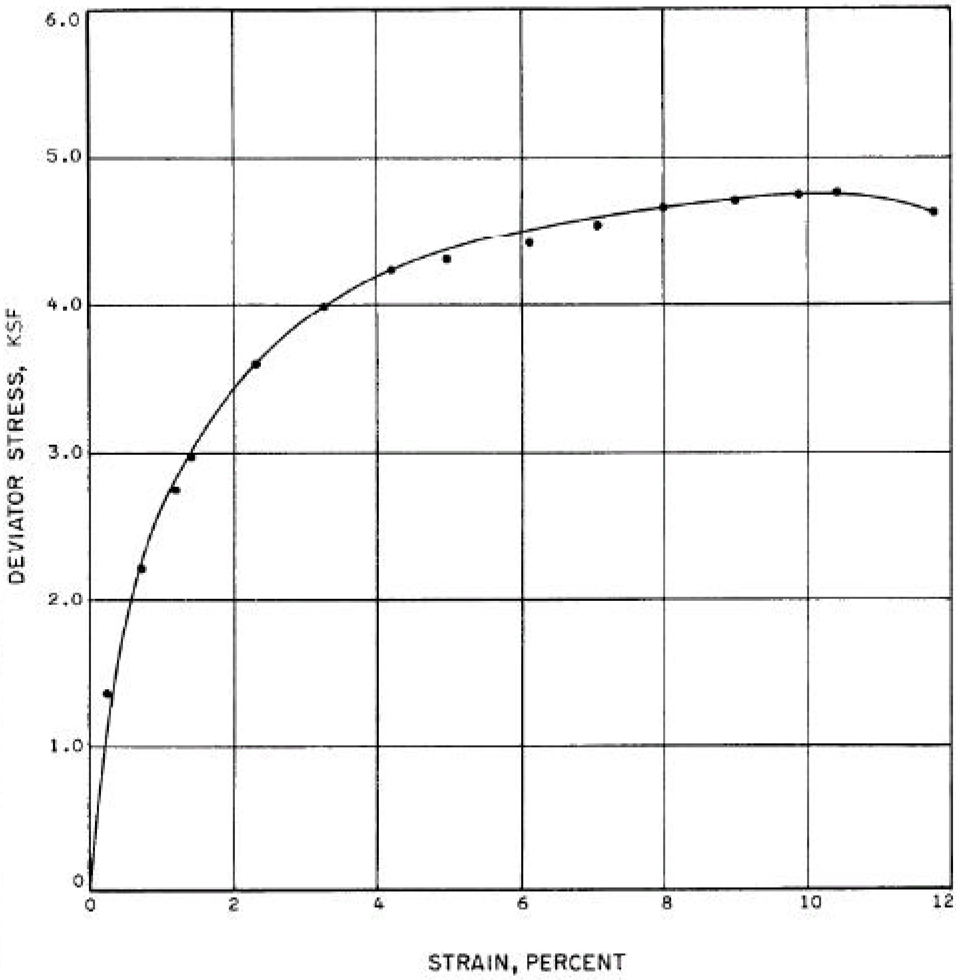
CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
11	21	103	10.80	STIFF OLIVE GRAY CLAY WITH SILT PARTINGS AND POCKETS
12	22	113	11.52	STIFF OLIVE GRAY CLAY WITH SAND PARTINGS AND POCKETS

STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

FUGRO
Consulting Engineers and Geologists

PLATE A-8

soil.max



CURVE NO.	SAMPLE NO.	DEPTH, FT.	CONFINING PRESSURE, KSF	MATERIAL
13	41	302	32.40	VERY STIFF OLIVE GRAY SILTY CLAY WITH SILT POCKETS

STRESS-STRAIN CURVES
TRIAXIAL COMPRESSION TEST
UNCONSOLIDATED-UNDRAINED

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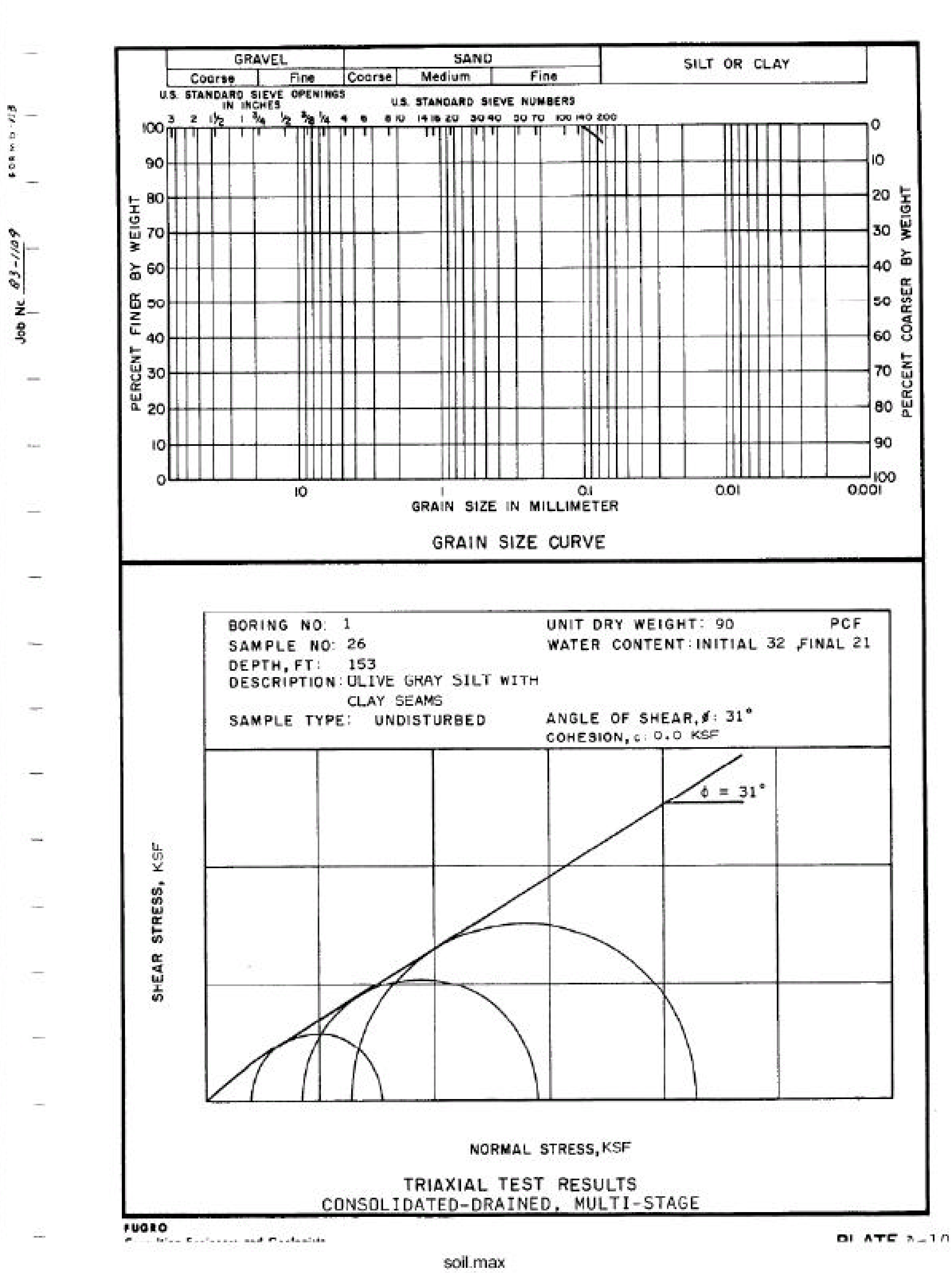
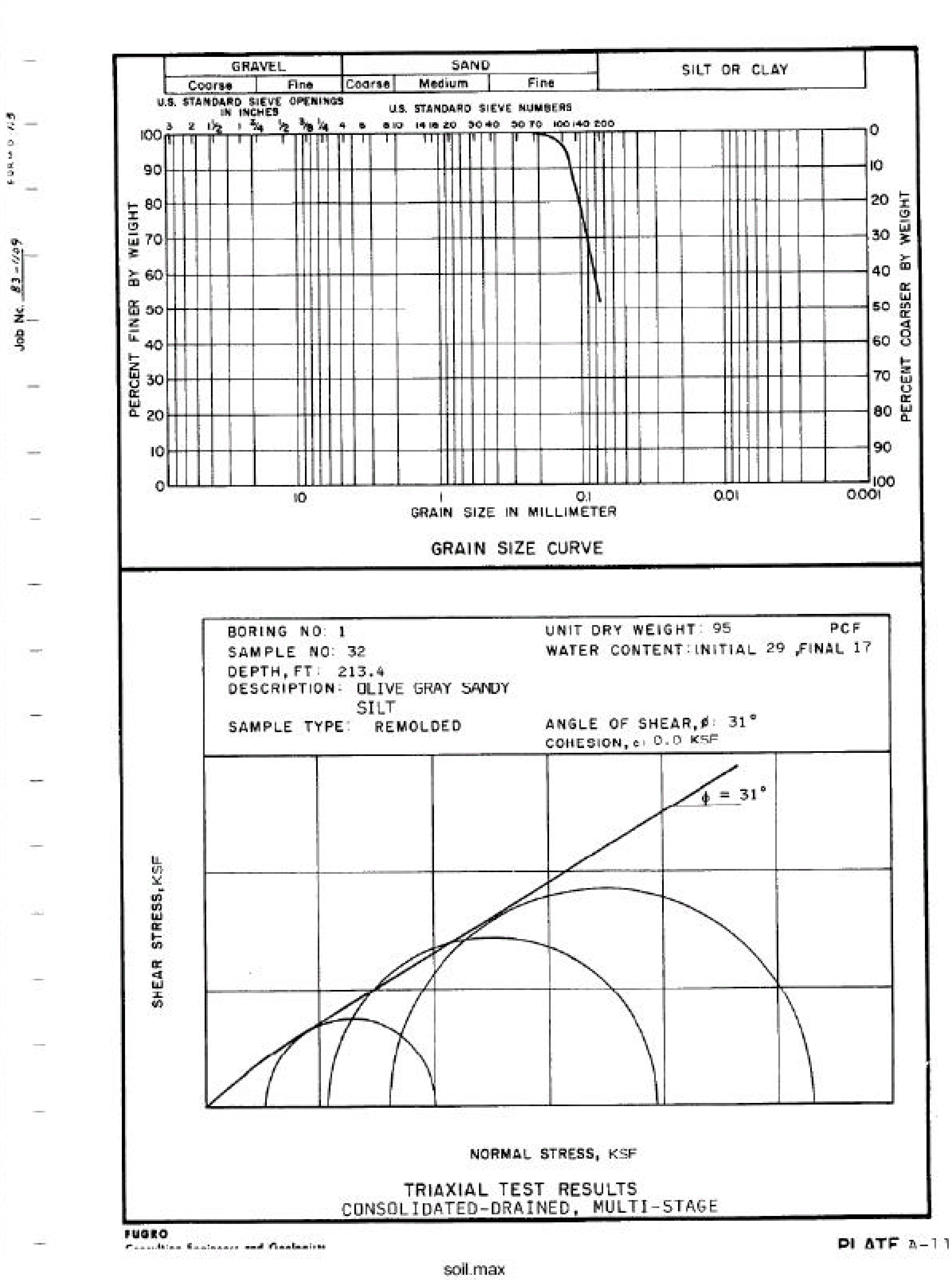
Consulting Engineers and Geologists

PLATE A-9

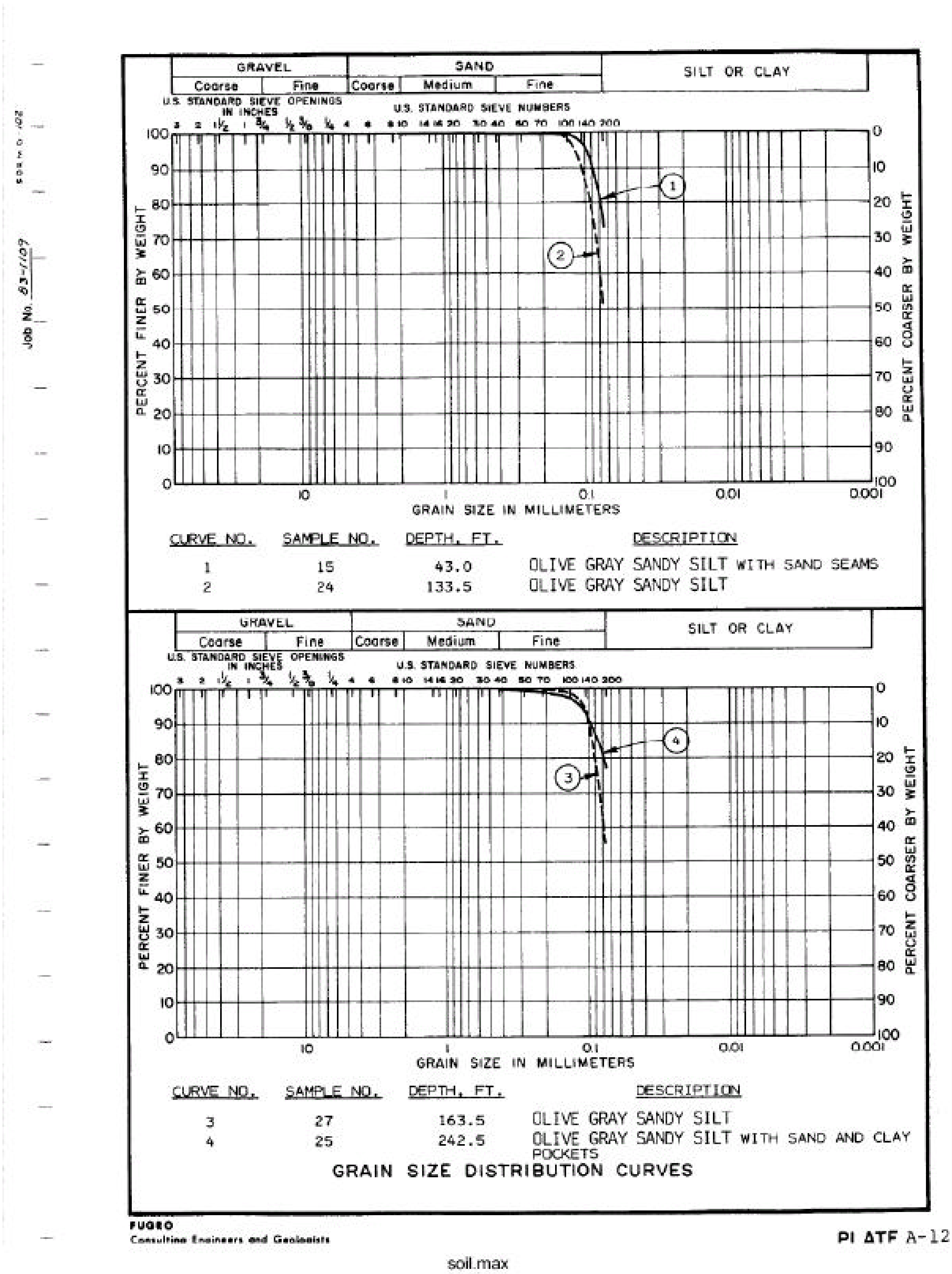
soil.max


GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT OR CLAY
U.S. STANDARD SIEVE OPENINGS IN INCHES
U.S. STANDARD SIEVE NUMBERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETER
GRAIN SIZE CURVE
BORING NO: 1
SAMPLE NO: 26
DEPTH, FT: 153
DESCRIPTION: OLIVE GRAY SILT WITH CLAY SEAMS
SAMPLE TYPE: UNDISTURBED
UNIT DRY WEIGHT: 90 PCF
WATER CONTENT: INITIAL 32 ,FINAL 21
ANGLE OF SHEAR, ϕ: 31°
COHESION, c: 0.0 KSF
ϕ = 31°
SHEAR STRESS, KSF
NORMAL STRESS, KSF
TRIAXIAL TEST RESULTS
CONSOLIDATED-DRAINED, MULTI-STAGE
FUGRO
Job No. 83-1109

soil.max


Job No. 83-1109
GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT OR CLAY
U.S. STANDARD SIEVE OPENINGS IN INCHES
U.S. STANDARD SIEVE NUMBERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETER
GRAIN SIZE CURVE
BORING NO: 1
SAMPLE NO: 32
DEPTH, FT: 213.4
DESCRIPTION: OLIVE GRAY SANDY SILT
SAMPLE TYPE: REMOLDED
UNIT DRY WEIGHT: 95 PCF
WATER CONTENT: INITIAL 29 ,FINAL 17
ANGLE OF SHEAR, ø: 31°
COHESION, c: 0.0 KSF
ϕ = 31°
SHEAR STRESS, KSF
NORMAL STRESS, KSF
TRIAXIAL TEST RESULTS
CONSOLIDATED-DRAINED, MULTI-STAGE
FUGRO
PLATE A-11

soil.max


GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT OR CLAY
U.S. STANDARD SIEVE OPENINGS IN INCHES
U.S. STANDARD SIEVE NUMBERS
PERCENT FINER BY WEIGHT
PERCENT COARSER BY WEIGHT
GRAIN SIZE IN MILLIMETERS
CURVE NO. SAMPLE NO. DEPTH, FT. DESCRIPTION
1 15 43.0 OLIVE GRAY SANDY SILT WITH SAND SEAMS
2 24 133.5 OLIVE GRAY SANDY SILT
CURVE NO. SAMPLE NO. DEPTH, FT. DESCRIPTION
3 27 163.5 OLIVE GRAY SANDY SILT
4 25 242.5 OLIVE GRAY SANDY SILT WITH SAND AND CLAY POCKETS
GRAIN SIZE DISTRIBUTION CURVES
FUGRO
Consulting Engineers and Geologists
PLATE A-12
Job No. 83-1109
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APPENDIX B

METHOD FOR PREDICTING PILE CAPACITIES

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APPENDIX B

METHOD FOR PREDICTING PILE CAPACITIES

CONTENTS

Page

METHOD FOR PREDICTING PILE CAPACITIES

Predetermination of the ultimate axial capacity of piles is defined using the static method of analysis. In this method, the ultimate compressive capacity, Q, for a given penetration is taken as the sum of the skin frictional capacity, Q_s, and the end bearing capacity, Q_p, so that

$$Q = Q_s + Q_p = fA_s + qA_p$$

where A_s and A_p represent, respectively, the embedded pile surface area and the pile tip area; f and q represent, respectively, the unit skin friction and the unit end bearing. When computing ultimate tensile capacity, the second term of this equation is neglected.

Cohesive Soils

API RP 2A, 1982 Method. According to the API RP 2A, 1982(1) recommendations, the unit skin friction, f, and therefore the frictional capacity, Q_s, of a pile driven in clay at any particular depth is related to the undraines shear strength, Su, of the clay.

The unit skin friction, f, may be equal to or less than, but not greater than Su, the undrained shear strength of the clay. In particular, for highly plastic clays such as those found in the Gulf of Mexico, f may be equal to Su for underconsolidated and normally consolidated clays. For overconsolidated clay, f shall not exceed 1/2 ton per square foot for shallow penetrations or the equivalent cohesion for a normally consolidated clay for deeper penetrations, whichever is greater.

(1) "Planning, Designing and Constructing Fixed Offshore Platforms", A Recommended Practice by American Petroleum Institute, API RP 2A, January, 1982.

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Unit end bearing in clay is estimated using the expression:

$$q = SuN_c'$$

where: Su = undrained cohesive shear strength

N_c = a dimensionless bearing capacity factor (N_c = 9 for deep footings).

Granular Soils

The frictional capacity contribution developed in granular soils is determined using the following equation:

$$f = K \bar{\sigma}_v \tan \delta$$

where: K = coefficient of lateral earth pressure

$\bar{\sigma}_v$ = effective vertical stress

δ = angle of friction between foundation soil and steel pile.

The value of K is taken as 0.7 for compressive loads and 0.5 for tensil loads. Effective vertical stress is computed from the submerged unit weight values.

Unit end bearing, q, for piles installed in granular soils is computed using the following equation:

$$q = \bar{\sigma}_v N_q$$

where: $\bar{\sigma}_v$ = effective vertical stress and

N_q = a dimensionless bearing capacity factor which is a function of Φ, the angle of internal friction of the soil

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The computed values of f and q are not allowed to exceed certain values[(2)] given in the table below:

Soil Type	ϕ	δ	f_{max} (ksf)	N_q	q_{max} (ksf)
Clean Sand	35°	30°	2.0	40	200
Silty Sand	30°	25°	1.7	20	100
Sandy Silt	25°	20°	1.4	12	60
Silt	20°	15°	1.0	8	40

(2) "Planning, Designing and Constructing Fixed Offshore Platforms", A Recommended Practice by American Petroleum Institute, API RP 2A, October, 1969.

CEOTECHNICAL INVESTIGATION
BORING 1, BLOCK 27
SOUTH TIMBALIER AREA
GULF OF MEXICO

* * *

R e p o r t

t o

Tenneco Oil Exploration and Production
Lafayette, Louisiana

* * *

by

M c C L E L L A N D E N G I N E E R S, I N C.
Geotechnical Consultants
Houston, Texas

October 1982

McCLELLAND ENGINEERS

McClelland engineers, inc. / geotechnical consultants
6100 HILLCROFT / HOUSTON, TEXAS 77081
TEL 713 / 772-3701 / TELEX 762-447

Report No. 0182-0645
October 22, 1982

Tenneco Oil Exploration and Production
Eastern Gulf Division
P. O. Box 39300
Lafayette, LA 70503

Attention: Mr. Dan Tennison

Geotechnical Investigation
Boring 1. Block 27
South Timbalier Area
Gulf of Mexico

McClelland Engineers, Inc., is pleased to submit this report on our geotechnical investigation conducted in the above offshore block. This study was authorized by Mr. H. C. Melancom in a letter dated September 13, 1982.

Advance final design information consisting of 1) ultimate pile capacity curves for 48-in.-diameter pipe piles and 2) lateral soil resistance-pile deflection (p-y) data for 48-in.-diameter pipe piles was sent to you on October 7, 1982. This information is included here together with all field and laboratory data.

We appreciate the opportunity to be of service to you on this project. Please call when we can be of further assistance.

Sincerely,

McCLELLAND ENGINEERS, INC.

Donald W. Armour, Jr.
Geotechnical Engineer

John P. Workman, P.E.
Engineer Manager

DWA/JPW/vls
Copies Submitted: (6)

C O N T E N T S

McCLELLAND ENGINEERS

ILLUSTRATIONS

SUMMARY

McClelland Engineers, Inc., conducted a geotechnical investigation in Block 27 of the South Timbalier Area, Gulf of Mexico. The purpose of our investigation was to obtain data to develop foundation design recommendations for an offshore jacket structure. A soil boring was drilled to 306.0-ft penetration below the seafloor in a water depth of 56 ft. Field and laboratory tests were conducted to determine the pertinent index and engineering properties of the soils encountered. Engineering analyses were performed to develop axial and lateral pile design data and pile installation recommendations.

The soils at the boring location consist primarily of soft to very stiff clay. Medium dense silty sand and sandy silt is present from 17 to 40-ft penetration and a stratum of very dense fine to medium sand is present below 260-ft penetration. Details of the soil stratigraphy are presented on the boring log.

This report presents pile design data for 48-in.-diameter driven pipe piles. Ultimate pile capacity curves were developed following the API RP 2A (January 1982) Method. Pile penetrations should be selected to provide factors of safety of at least 2.0 with respect to normal operating loads and at least 1.5 with respect to maximum design storm loads. Soil resistance-pile deflection (p-y) data for performing lateral load analyses were developed using the procedures recommended in API RP 2A (January 1982) for cyclic loading conditions.

Ultimate seafloor bearing capacity, q_u, in kips per sq ft may be computed using the following equation:

$$q_u = (1.8 + 0.024B)(1 + 0.2B/L)$$

where B and L are the width and length of the bearing area in ft, respectively. We recommend a factor of safety of at least 1.5 be used for the design of mud mats and horizontal bracing members.

A brief discussion is presented on pile installation, including comments on supplementary pile installation techniques. Pile drivability can be investigated by wave equation analyses when design penetrations and tentative hammer and wall-thickness schedules are determined.

INTRODUCTION

Purpose and Scope

McClelland Engineers, Inc., conducted a geotechnical investigation to develop information on soil and foundation conditions at a site in Block 27 of the South Timbalier Area in the Gulf of Mexico. The purpose of our study was to develop foundation design recommendations for an offshore jacket structure. To accomplish our purpose the following tasks were performed:

(1) A soil boring was drilled to 306.0-ft penetration below the seafloor to explore the subsurface stratigraphy and obtain soil samples for testing;

(2) Field and laboratory tests were conducted to evaluate the pertinent index and engineering properties; and

(3) Engineering analyses were performed to develop pile design parameters and installation considerations for an offshore jacket structure.

Report Format

The initial sections of this report contain brief descriptions of the field and laboratory phases of our study. A general soils description is then presented followed by a discussion of axial and lateral pile design and platform jacket support. A section on pile installation concludes the text of this report. Detailed discussions of the field and laboratory investigations and axial pile design are presented in the appendices.

FIELD AND LABORATORY INVESTIGATIONS

Exploratory Boring

Soil conditions at the site were explored by a soil boring drilled to 306.0-ft penetration below the seafloor. Our field investigation was accomplished using our drilling vessel the M/V "R. L. Perkins" which was moored to the south side of Tenneco's Platform "E". The approximate coordinates of our boring are x = 2,362,000 and y = 118,110. A water depth of 56 ft was measured at 2100 hours on September 17, 1982, using a weighted wire line. The sampling depths were not corrected for tidal variation since the variation in in the Gulf of Mexico is generally less than 1 ft.

Field and Laboratory Tests

After the samples were recovered from the boring, we tested a limited number in the field with a miniature vane and Torvane. All of the samples were shipped to our Houston laboratory where Atterberg limits, water content tests, and grain size analyses were performed to confirm the field classifications. We also conducted miniature vane and unconsolidated-undrained triaxial compression tests to determine the shear strength of the cohesive soils.

A detailed description of our field and laboratory procedures is presented in Appendix A. The time summary of field operations is presented on Plate A-1. The Summary of Test Results, type and number of tests, grain size analyses, and stress-strain curves are shown on Plates A-2 through A-6.

GENERAL SOIL CONDITIONS

Soil Stratigraphy

A generalized summary of the major soil strata at this site based on the boring log presented on Plates 1 and 2 is given in the following tabulation:

Stratum	Penetration, ft From	To	Description
I	0	17	Soft to firm clay
II	17	40	Medium dense silty sand and sandy silt
III	40	260	Firm to very stiff clay
IV	260	306+	Very dense fine to medium sand

Detailed soil descriptions that include textural variations and inclusions within each stratum are noted on the boring log.

Interpretation of Soil Properties

The shear strength and submerged unit weight profiles shown on Plates 3 and 4, respectively, represent our interpretation of the assembled test results as plotted on Plates 1 and 2. These profiles were used to develop pile foundation design and installation recommendations.

In developing the shear strength profile for the cohesive soils, undrained shear strength test results from miniature vane and unconsolidated-undrained triaxial compression tests were analyzed. The shear strength profile considered to best represent the shear strength at the site is shown on Plate 3.

Strength parameters for granular soils were selected based on their gradation and density as revealed by grain size analysis and driving resistance during percussion sampling. The submerged unit weight profile shown on Plate 4 was developed from measured values for cohesive soils and from assumed values based on correlations of unit weight with gradation and relative density of granular soils.

Subsequent recommendations for pile design and installation contained in this report were developed assuming that soil conditions as revealed by the boring are continuous throughout the general area of the boring location. Consideration of possible stratigraphic changes, faulting, or other differences in soil conditions that might influence foundation design was beyond the scope of this investigation.

AXIAL PILE ANALYSIS

Method of Analysis

The ultimate axial capacity of piles was computed using the static method of analysis. In this method the ultimate compressive capacity of a pile, for a given penetration is taken as the sum of the skin friction on the pile wall and the end bearing on the pile tip. The weight of the pile and soil plug are neglected in the computations. When computing ultimate tensile capacity the end bearing component is also neglected.

Ultimate Pile Capacity Curves

The unit skin friction and unit end bearing values plotted on Plates 5 and 6 were used to compute pile capacity by the API RP 2A (January 1982) Method. The ultimate compressive and tensile capacities were computed for 48-in.-diameter open-end pipe piles driven to various penetrations at the boring location. Ultimate pile capacity curves computed by the API RP 2A Method are presented on Plate 7. A discussion of our application of this method is presented in Appendix B.

We recommend that pile penetrations be selected to provide factors of safety of at least 2.0 with respect to normal operating loads and at least 1.5 with respect to maximum storm loads.

LATERAL PILE DESIGN ANALYSIS

Assuming that a computer solution based on the difference equation method will be employed in lateral load analyses, input information to reflect the soil resistance-pile deflection (p-y) characteristics of the soils at the boring location was developed for individual 48-in.-diameter pipe piles. The p-y data were developed to 100-ft penetration using the procedures proposed by Matlock (1970) and Reese, et al (1974) and outlined in API RP 2A (January 1982) for soft clay and sand, respectively, subjected to cyclic loading. The soil stratigraphy and parameters used in developing the p-y data are presented on Plate 8. The p-y data generated for individual 48-in.-diameter pipe piles are presented on Plate 9.

PLATFORM JACKET SUPPORT

Due to the presence of soft to firm clay from the seafloor to 17-ft penetration, we expect nominal 5 to 10-ft jacket leg extensions to penetrate fully at the boring location. Mud mats may be required to prevent excessive penetration of the platform jacket below the seafloor. In addition to the mud mats, the lowest horizontal bracing members bearing on the seafloor may provide support for the jacket structure. The ultimate bearing pressure for bracing member and for design of mud mats should be determined using the following equation:

$$q_u = (1.8 + 0.024B)(1 + 0.2B/L)$$

where q_u = ultimate bearing pressure, ksf
B = diameter of tubular member or width of mud mat, ft
L = length of tubular member or mud mat, ft

For horizontal tubular members, B will be equal to the member width at the soil surface or the member diameter if the member penetrates one radius or more. For triangular shaped mud mats, B should be taken as the least altitude and L should be taken as the longest side.

The above equation for ultimate bearing capacity includes the effects of the size and shape of the foundation element bearing on the seafloor in addition to the influence of increasing soil shear strength with depth. The equation does not include the effects of any significant vertical platform velocities at the time of placement. A safety factor of at least 1.5 should be applied to the ultimate bearing capacity obtained from the above equation.

PILE INSTALLATION CONSIDERATIONS

Supplementary Procedures

The most economical pile installation procedure is by driving alone without resorting to supplemental procedures. The computed ultimate capacity of driven pipe piles presented on Plate 7 is based on the assumption that the piles will be driven to the desired penetration without supplemental drilling or jetting. However, unfavorable soil conditions and driving equipment problems can prevent piles from being driven to the desired penetrations. Such problems as clay set-up during delays in driving or the inability to drive through dense sand strata can prevent the desired pile penetration from being achieved. When techniques other than driving are used to aid pile installation, conditions assumed in computations based on driving alone may not be met, and computed capacities must frequently be adjusted to fit actual installation conditions. Supplementary pile installation procedures that may be used under various circumstances, including the possible effects that the procedures may have on pile capacity, have been presented by Sullivan and Ehlers (1972). Application of these or other procedures to aid ordinary driving requires field decisions that take into account many factors beyond the scope of our report. We recommend that supplementary procedures be chosen and applied under close engineering supervision, considering not only construction expendiency, but also design adequacy.

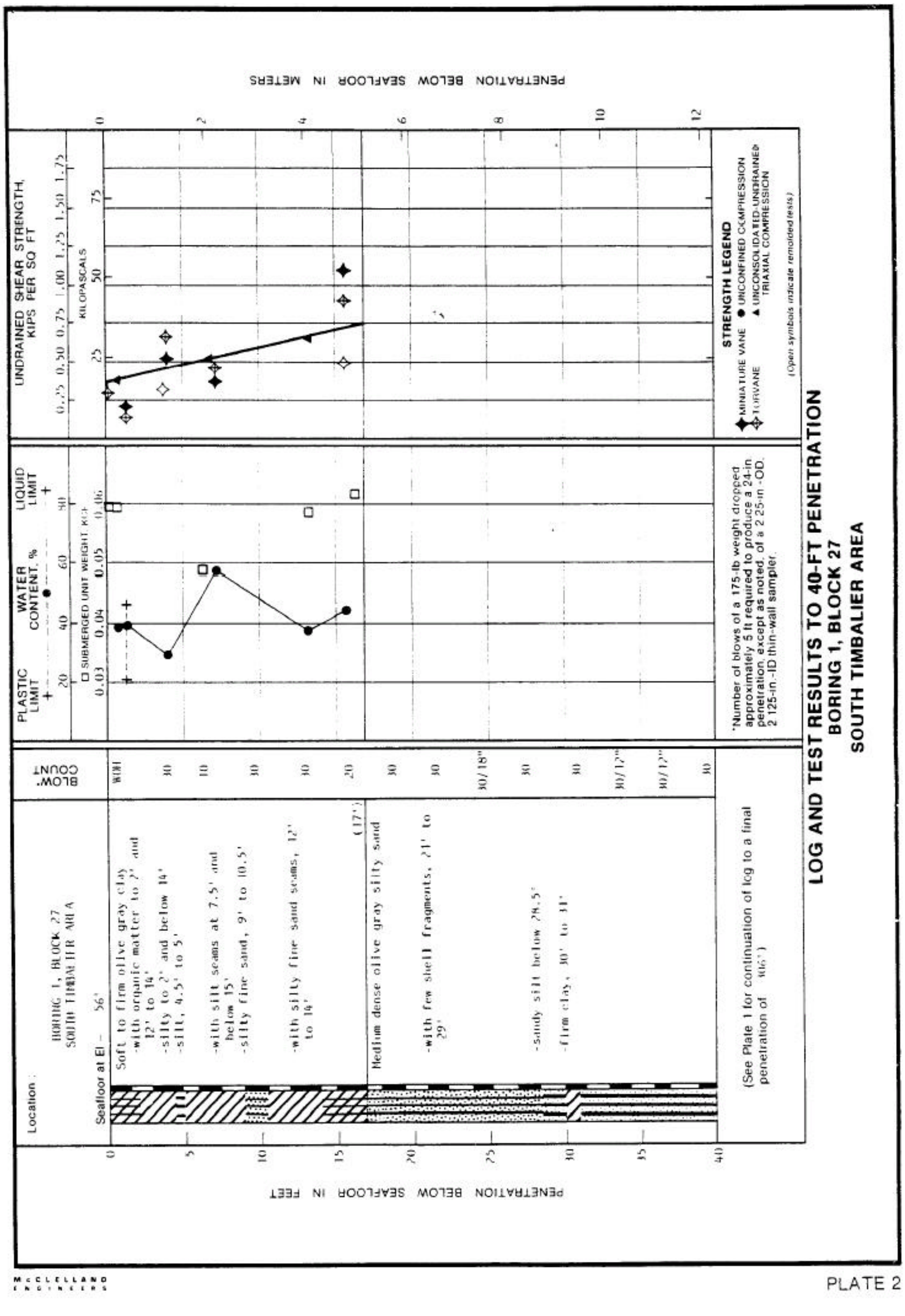
Drivability Analysis

Pile drivability can be investigated when pile design penetration and a tentative wall-thickness schedule and hammer size are known. A pile drivability study consists of three parts. First, the resistance to driving is estimated from soil properties at the site. Second, the driving resistance that can be overcome by a particular hammer-pile-soil system is computed from a wave equation analysis. Third, these results are compared and an assessment of pile drivability is made taking into consideration judgment and past experience.

The driving records of piles at a particular site often show considerable scatter because of variation in soil conditions, hammer performance, and cushion properties. Additional factors affecting drivability are setup time during interruptions in driving and plug behavior. For these reasons, drivability studies should be used to predict a range in blow counts. Effects on drivability due to variations of hammer efficiency, cushion properties, minimum wall thickness, percent tip resistance, soil quake, and soil damping parameters may be investigated using the wave equation computer program. We have the capability to evaluate drivability and are prepared to begin our analysis at your request.

ILLUSTRATIONS

McCLELLAND ENGINEERS



McCLELLAND ENGINEERS

PLATE 2

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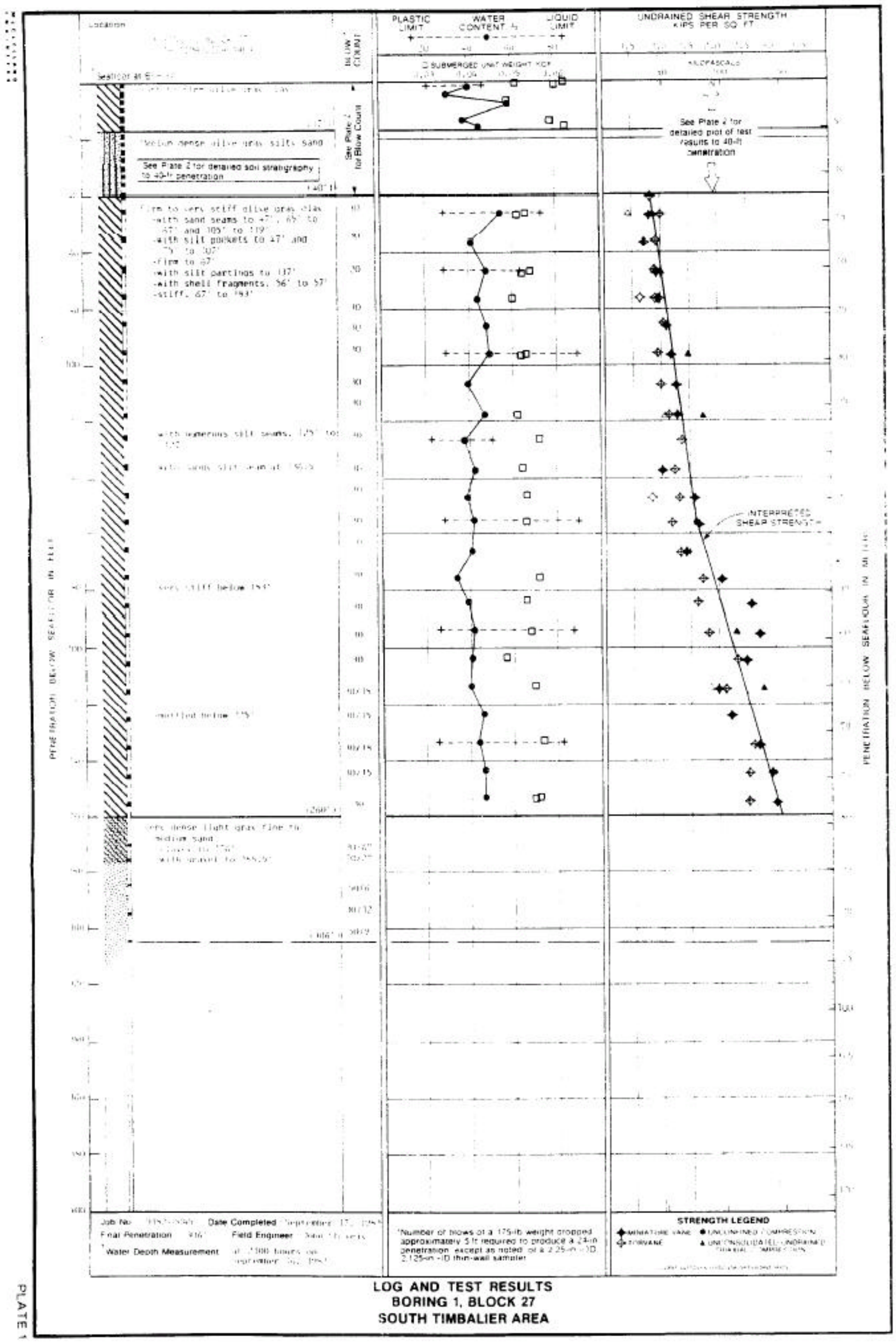
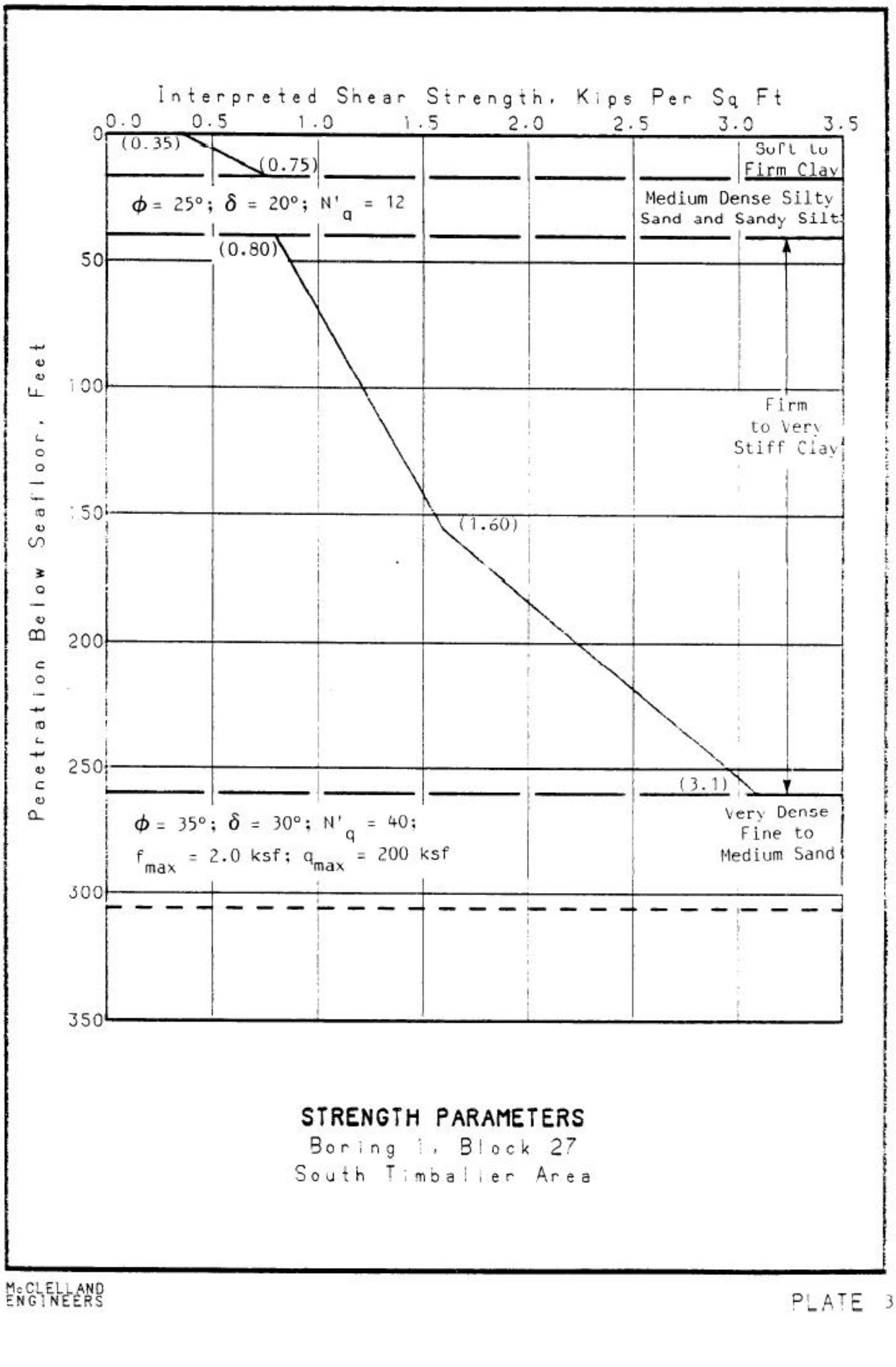
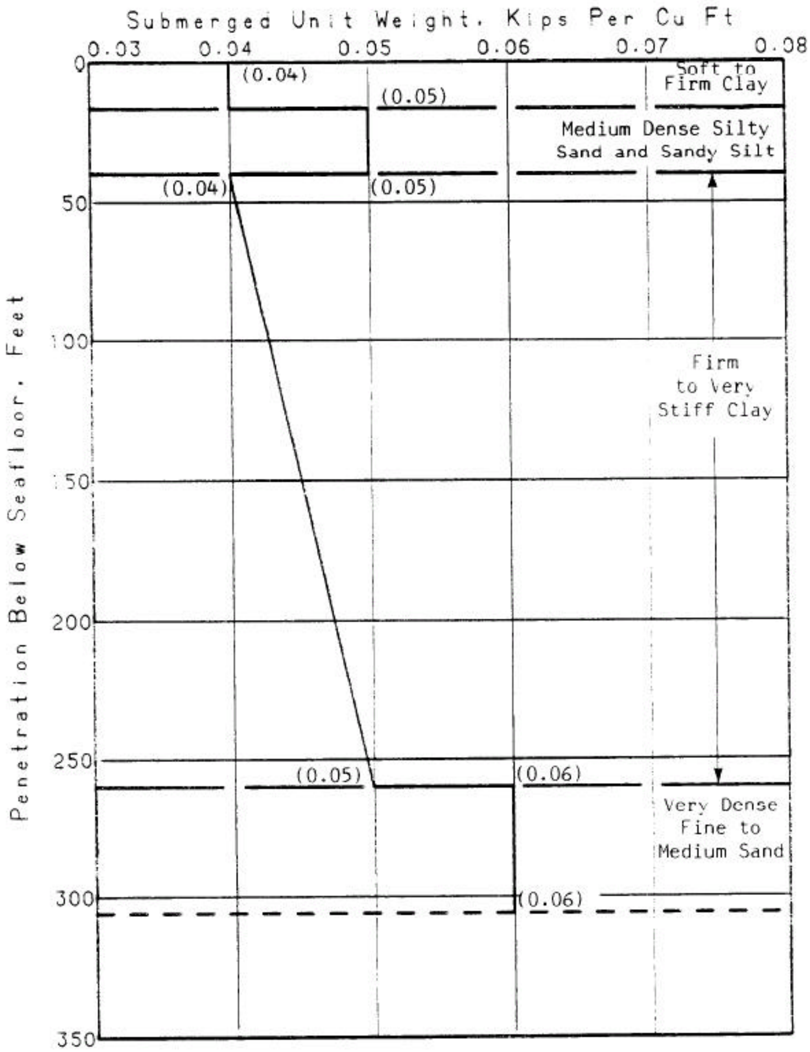

PLASTIC LIMIT
WATER CONTENT %
LIQUID LIMIT
UNDRAINED SHEAR STRENGTH KIPS PER SQ FT
See Plate 2 for detailed soil stratigraphy to 40-ft penetration
See Plate 2 for detailed plot of test results to 40-ft penetration
INTERPRETED SHEAR STRENGTH
PENETRATION BELOW SEAFLOOR IN FEET
PENETRATION BELOW SEAFLOOR IN METERS
STRENGTH LEGEND
LOG AND TEST RESULTS
BORING 1, BLOCK 27
SOUTH TIMBALIER AREA
PLATE 1

soil.max


Interpreted Shear Strength, Kips Per Sq Ft
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Penetration Below Seafloor, Feet
0
50
100
150
200
250
300
350
(0.35)
(0.75)
(0.80)
(1.60)
(3.1)
Soft to Firm Clay
ϕ = 25°; δ = 20°; N'_q = 12
Medium Dense Silty Sand and Sandy Silt
Firm to Very Stiff Clay
ϕ = 35°; δ = 30°; N'_q = 40;
f_{max} = 2.0 ksf; q_{max} = 200 ksf
Very Dense Fine to Medium Sand
STRENGTH PARAMETERS
Boring 1, Block 27
South Timbalier Area
McCLELLAND ENGINEERS
PLATE 3

soil.max



SUBMERGED UNIT WEIGHT
Boring 1, Block 27
South Timbalier Area

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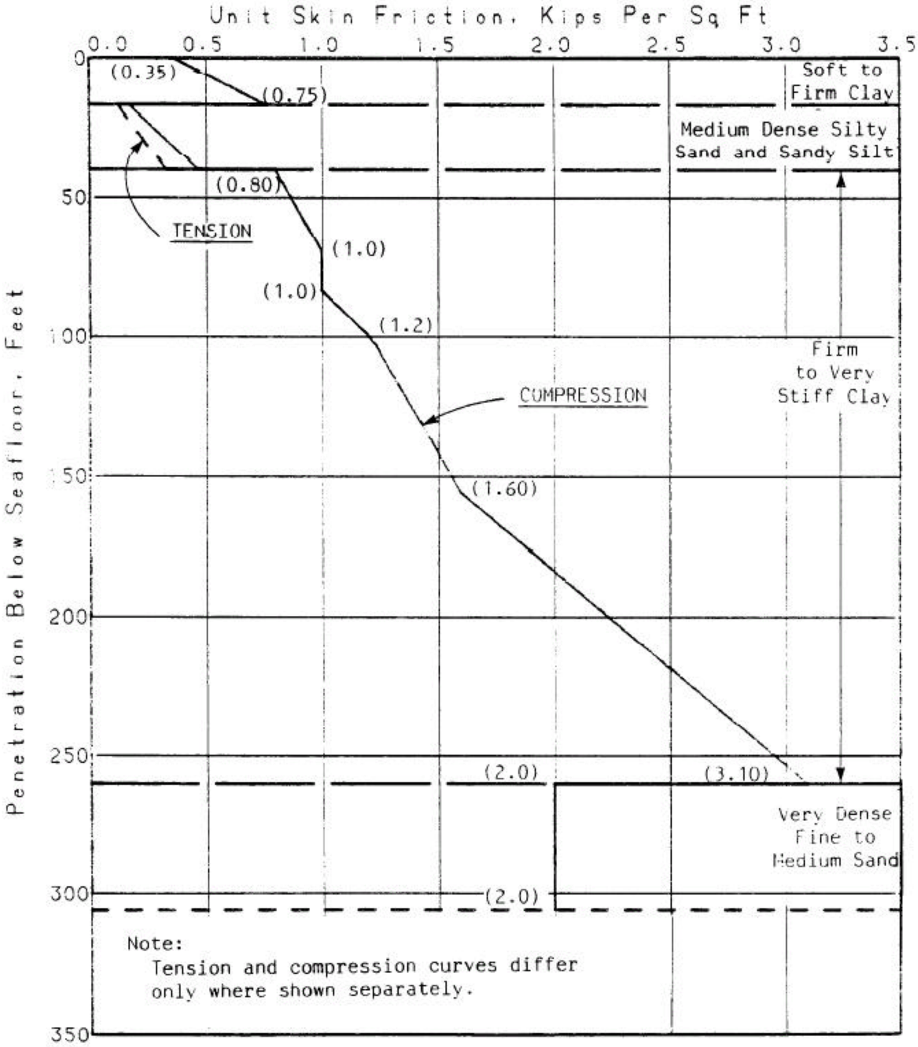
PLATE 4

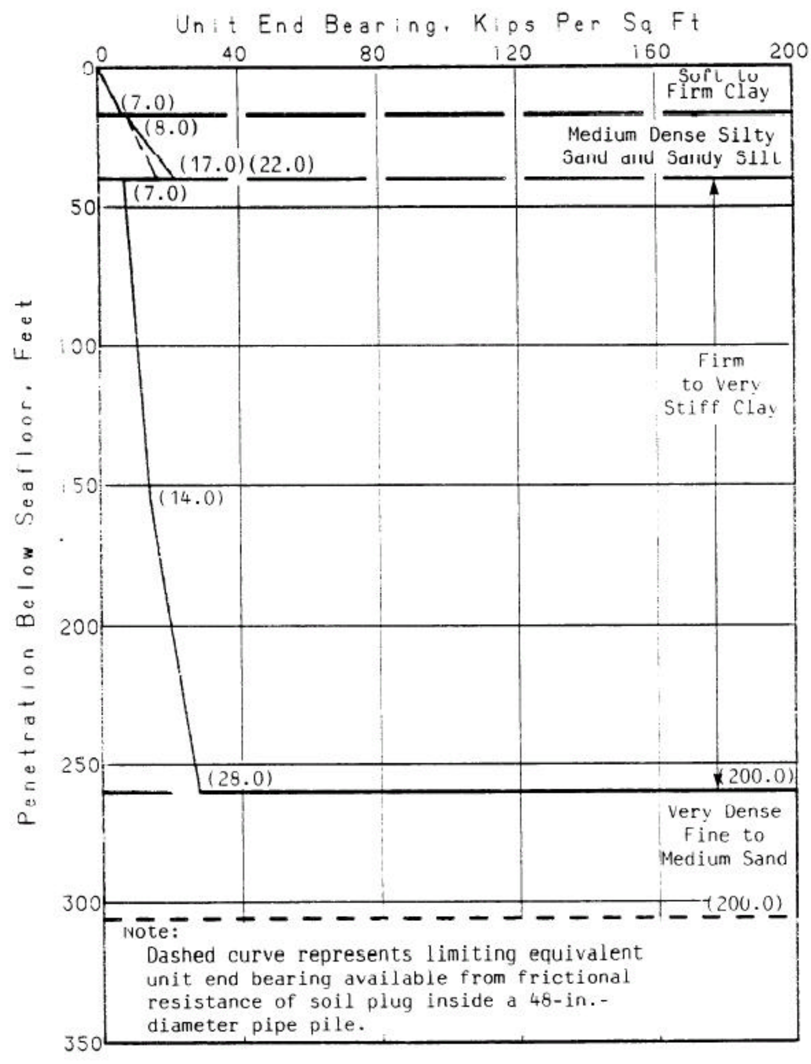
soil.max



UNIT SKIN FRICTION
API RP 2A Para. 2.6.4b.1
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 5

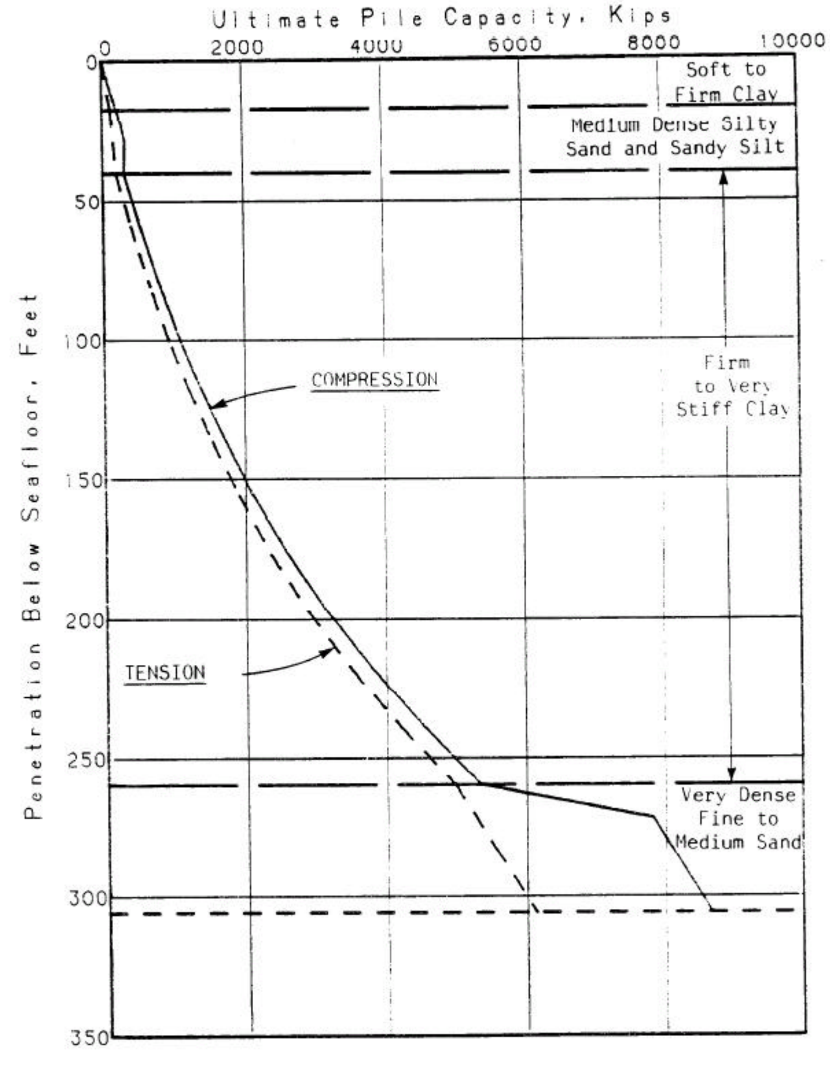


UNIT END BEARING
API RP 2A Para. 2.6.4b.1
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 6

soil.max

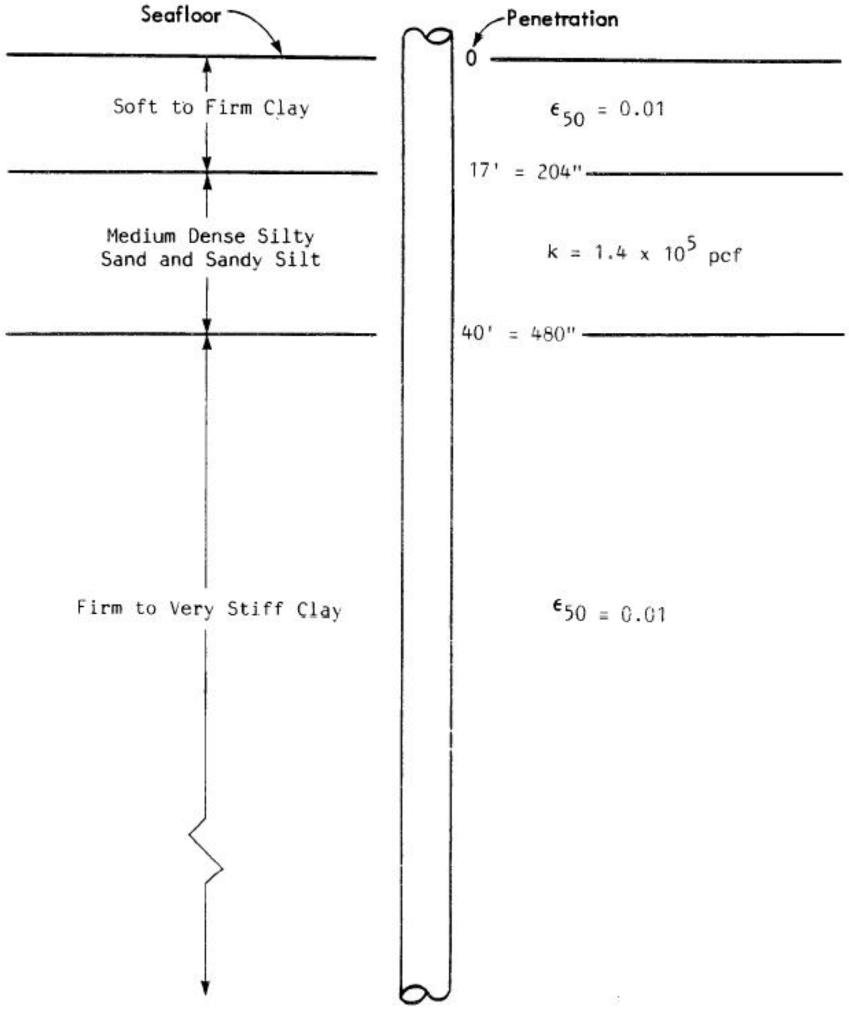


ULTIMATE PILE CAPACITY
48-in.-Diameter Driven Pipe Piles
API RP 2A Para. 2.6.4b.1
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 7

soil.max



Notes:
1. ϵ_{50} is axial stain at half of peak deviator stress for clays.
2. k is constant of horizontal subgrade reaction for sands and clays.
3. Undrained shear strenght values for clays, angle of internal friction for sands and submerged unit weights for clays and sands are shown on "Interpretation of Data", Plate.

STRATIGRAPHY AND PARAMETERS FOR P-Y DATA
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 5

soil.max

COORDINATES OF CURVE POINTS	PENETRATION, INCHES									
	0.	48.	96.	144.	204.	205.	252.	300.	360.	420.
Y(1)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
P(1)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
Y(2)	0.03	0.03	0.03	0.03	0.03	0.07	0.07	0.07	0.07	0.07
P(2)	53.	85.	122.	164.	223.	262.	414.	581.	828.	1118.
Y(3)	0.06	0.06	0.06	0.06	0.06	0.13	0.13	0.13	0.13	0.13
P(3)	66.	107.	154.	207.	281.	371.	577.	810.	1155.	1559.
Y(4)	0.12	0.12	0.12	0.12	0.12	0.20	0.20	0.20	0.20	0.20
P(4)	84.	135.	194.	261.	354.	455.	701.	984.	1403.	1894.
Y(5)	0.24	0.24	0.24	0.24	0.24	0.27	0.27	0.27	0.27	0.27
P(5)	105.	171.	245.	329.	446.	525.	805.	1130.	1611.	2174.
Y(6)	0.48	0.48	0.48	0.48	0.48	0.33	0.33	0.33	0.33	0.33
P(6)	133.	215.	309.	414.	562.	587.	896.	1258.	1793.	2420.
Y(7)	0.96	0.96	0.96	0.96	0.96	0.40	0.40	0.40	0.40	0.40
P(7)	167.	271.	389.	521.	708.	643.	978.	1373.	1957.	2641
Y(8)	1.20	1.20	1.20	1.20	1.20	0.47	0.47	0.47	0.47	0.47
P(8)	180.	292.	419.	562.	762.	695.	1053.	1478.	2107.	2844.
Y(9)	1.50	1.50	1.50	1.50	1.50	0.53	0.53	0.53	0.53	0.53
P(9)	194.	314.	451.	605.	821.	743.	1123.	1576.	2247.	3032.
Y(10)	1.80	1.80	1.80	1.80	1.80	0.60	0.60	0.60	0.60	0.60
P(10)	206.	334.	479.	643.	873.	788.	1188.	1668.	2377.	3208.
Y(11)	2.10	2.10	2.10	2.10	2.10	0.67	0.67	0.67	0.67	0.67
P(11)	217.	351.	505.	677.	919.	831.	1249.	1754.	2501	3375.
Y(12)	2.40	2.40	2.40	2.40	2.40	0.73	0.73	0.73	0.73	0.73
P(12)	227.	367.	528.	708.	961.	872.	1308.	1837.	2618.	3533.
Y(13)	3.00	3.00	3.00	3.00	3.00	0.80	0.80	0.80	0.80	0.80
P(13)	244.	396.	568.	762.	1035.	911.	1364.	1915.	2729.	3683.
Y(14)	3.60	3.60	3.60	3.60	3.60	1.13	1.13	1.13	1.13	1.13
P(14)	260.	421.	604.	810.	1100.	1101.	1636.	2298.	3275.	4420.
Y(15)	9.60	9.60	9.60	9.60	9.60	1.47	1.47	1.47	1.47	1.47
P(15)	151.	270.	419.	599.	872.	1291.	1909.	2681.	3821.	5157.
Y(16)	18.00	18.00	18.00	18.00	18.00	1.80	1.80	1.80	1.80	1.80
P(16)	0.	60.	159.	303.	553.	1481.	2182.	3064.	4367.	5894.
Y(17)	24.00	24.00	24.00	24.00	24.00	48.00	48.00	48.00	48.00	48.00
P(17)	0.	60.	159.	303.	553.	1481.	2182.	3064.	4367.	5894.

Notes :
1. "Y" is deflection in inches.
2. "P" is soil resistance in pounds per inch.

(Continued on Plate 9b)

P-Y DATA
48-in.-Diameter Pipe Pile
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 9a

soil.max

COORDINATES OF CURVE POINTS	PENETRATION, INCHES				
	480.	481.	720.	840.	1200.
Y(1)	0.00	0.00	0.00	0.00	0.00
P(1)	0.	0.	0.	0.	0.
Y(2)	0.07	0.03	0.03	0.03	0.03
P(2)	1449.	351.	411.	442.	532.
Y(3)	0.13	0.06	0.06	0.06	0.06
P(3)	2021.	442.	518.	556.	671.
Y(4)	0.20	0.12	0.12	0.12	0.12
P(4)	2456.	557.	653.	701.	845.
Y(5)	0.27	0.24	0.24	0.24	0.24
P(5)	2819.	702.	823.	883.	1065.
Y(6)	0.33	0.48	0.48	0.48	0.48
P(6)	3138.	885.	1037.	1113.	1342.
Y(7)	0.40	0.96	0.96	0.96	0.96
P(7)	3425.	1115.	1306.	1402.	1690.
Y(8)	0.47	1.20	1.20	1.20	1.20
P(8)	3688.	1201.	1407.	1511.	1821.
Y(9)	0.53	1.50	1.50	1.50	1.50
P(9)	3932.	1294.	1516.	1627.	1962.
Y(10)	0.60	1.80	1.80	1.80	1.80
P(10)	4161.	1375.	1611.	1729.	2085.
Y(11)	0.67	2.10	2.10	2.10	2.10
P(11)	4377.	1447.	1696.	1820.	2194.
Y(12)	0.73	2.40	2.40	2.40	2.40
P(12)	4581.	1513.	1773.	1903.	2294.
Y(13)	0.80	3.00	3.00	3.00	3.00
P(13)	4777.	1630.	1910.	2050.	2471.
Y(14)	1.13	3.60	3.60	3.60	3.60
P(14)	5732.	1732.	2029.	2179.	2626.
Y(15)	1.47	9.60	9.60	9.60	9.60
P(15)	6688.	1732.	2029.	2179.	2626.
Y(16)	1.80	18.00	18.00	18.00	18.00
P(16)	7643.	1732.	2029.	2179.	2626.
Y(17)	48.00	24.00	24.00	24.00	24.00
P(17)	7643.	1732.	2029.	2179.	2626.

Notes:
1. "Y" is deflection in inches.
2. "P" is soil resistance in pounds per inch.

(Continued from Plate 9a)

P-Y DATA
48-in.-Diameter Pipe Pile
Boring 1, Block 27
South Timbalier Area

McCLELLAND ENGINEERS

PLATE 9b

soil.max

APPENDIX A

FIELD AND LABORATORY INVESTIGATIONS

CONTENTS

ILLUSTRATIONS

McCLELLAND ENGINEERS

FIELD AND LABORATORY INVESTIGATIONS

Field Investigation

Soil information included in this report was obtained by a boring drilled with a Failing 2000 rotary drilling rig mounted over a center-well installed through the hull of our drilling vessel, M/V "R. L. Perkins." Personnel for carrying out drilling and sampling operations included a geotechnical engineer, two soil technicians, two drillers, and four drillers' helpers. A brief chronological summary of the field operations is presented on Plate A-1.

Drilling and sampling were accomplished by rotary drilling procedures using 3-1/2-in.-IF drill pipe. The drilling was performed using a drag bit attached to the drill pipe. Salt water gel and barite weight materials were used to suspend and remove drill cuttings and to provide lateral pressure to support the sides of the borehole.

A 2.25-in.-OD, 2.125-in.-ID thin-walled tube sampler was used to sample soils at regular intervals to the final penetration. The sampler was driven into the soil with a 175-lb sliding weight dropped about 5 ft to secure the desired penetration. Soil samples were obtained at about 3-ft intervals to 40-ft penetration and at about 10-ft intervals thereafter.

Each sample was extruded from the sampler in the field and then was carefully examined and classified by our field engineer or soil technician. Representative portions of each sample recovered were appropriately packaged for shipment to our laboratory in Houston.

Field and Laboratory Tests

Plate A-3 presents a summary of the laboratory tests performed. A summary of laboratory test results is presented on Plate A-2. The test procedures, which are in general accordance with ASTM, Part 19 (1982), are described in the following paragraphs.

Classification Tests. Plastic and liquid limits, collectively termed Atterberg limits and water content were determined for selected cohesive samples to provide information for soil classification. Water content and density determinations were made for soil compression test specimens. All of the above data are tabulated on the Summary of Test Results and are also plotted on the boring log.

Grain size analyses performed on granular soil samples included sieve analysis and the percent material passing the No. 200 sieve. The percentage of material passing the No. 200 sieve was determined as a routine part of the sieve analyses and for additional selected samples. Grain size curves are presented in the illustrations that follow this appendix.

Strength Tests. The undrained shear strength of cohesive samples were obtained from Torvane, miniature vane, and unconsolidated-undrained triaxial compression tests. The results are tabulated on the Summary of Test Results and are plotted on the boring log.

The Torvane is a small hand-operated device consisting of a metal disc with thin, radial vanes projecting from one face. The disc is pressed against a flat surface of the soil until the vanes are fully embedded, and rotated through a torsion spring until the soil is sheared. The device is calibrated to indicate shear strength of the soil directly from the rotation of the torsion spring.

The miniature vane test is used to determine the undrained shear strength of cohesive soils. In this test, a small 4-bladed vane is inserted into an undisturbed cohesive specimen. Torque is applied to the vane through a calibrated spring until soil shear failure occurs. The undrained shear strength is determined by multiplying the rotation, in degrees, by the spring constant.

In the unconsolidated-undrained triaxial compression test a soil specimen is enclosed in a thin rubber membrane and subjected to a confining pressure at least equal to the computed effective overburden pressure. The specimen is then loaded axially to failure at a nearly constant rate of strain without allowing drainage. The undrained shear strength of cohesive soils is computed as one half the maximum observed deviator stress. Selected stress-strain curves are presented on plates that accompany this appendix.

APPENDIX A

ILLUSTRATIONS

Date	Time From	Time To	Description of Activity
September 16, 1982	----	1245	M/V "R.L. Perkins" departs previous client's location
	1245	1930	Traveling to Block 27, South Timbalier Area
	1930	2045	Setting anchors
	2045	2400	Drilling and sampling
September 17, 1982	0000	1215	Drilling and sampling, Boring 1 completed at 305-ft penetration, used 135 bags of saltwater gel material and 312 bags of weight material
	1215	1300	Pulling anchors
	1300	----	M/V "R.L. Perkins" departs for next client's location

SUMMARY OF FIELD OPERATIONS
Boring 1, Block 27
South Timbalier Area

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PLATE A-1

soil.max

SUMMARY OF TEST RESULTS

SAMPLE NUMBER	PENETRATION FEET	CLASSIFICATION TESTS: LIQUID LIMIT	PLASTIC LIMIT	WATER CONTENT, %	UNIT WET WEIGHT, LB/CU FT	PERCENT PASSING NO 200 SIEVE	TORVANE: SHEAR STRENGTH KIPS/SQ FT	MINIATURE VANE: TYPE OF TEST	SHEAR STRENGTH KIPS/SQ FT	COMPRESSION TESTS: TYPE OF TEST	WATER CONTENT, %: Initial	Final	UNIT DRY WEIGHT, LB/CU FT	SHEAR STRENGTH, KIPS/SQ FT	ϵ_{50} STRAIN, %	LATERAL PRESSURE, KIPS/SQ FT	FAILURE STRAIN, %	TYPE OF FAILURE
1	0.5				114		0.29											
2	1.0				114					2-U^b	39		82	0.38	1.0	0.1	10.5	A
3	1.5	47	21	40			0.14	U	0.21									
5	4.3			30			0.66	U R	0.53 0.32									
7	6.5				103													
8	7.0				105					2-U^b	59		66	0.53	0.8		7.0	A
9	7.5			58			0.46	U	0.38									
12	13.5				113					2-U^b	38		82	0.66	2.6	0.6	14.0	A
13	14.0			40														
14	16.0			45			0.90	U R	1.09 0.49									
15	16.5				116													
16	17.0					49												
18	22.0					16a												
22	31.5					65												
25	40.0					92												
26	40.5						0.80											
27	46.0	73	28		107					2-U^b 2-R	54 52		69 68	0.85 0.41	0.8	2.0 2.0	9.6 12.5	A A,C
28	46.5			51			0.96	U	0.77									
29	55.5				105													
30	56.0						0.88											
31	56.5			41				U	0.67									
33	66.5	63	28		108					2-U^b	48		73	0.98	1.1	2.9	10.5	A
34	67.0			41			0.86	U	0.89									
35	76.0						0.86	U	0.91									
36	76.5			44	104			R	0.60									
38	86.0						1.06	U	1.07									
39	86.5			48														
40	96.0	89	29		107		0.90			2-U^b	49		72	1.46	1.7	4.2	5.3	A
42	105.5			42	106			U	1.13									
44	106.5			39			0.96	U	1.22									
45	117.8				105					2-U 2-R	47 48		72 73	1.71 1.07		5.3 5.3	5.3 14.5	A,C A,C
46	118.5			40			1.10	U	1.25									
47	126.0				110													

(Continued on Plate A-2a)

LEGEND AND NOTES

TYPE OF TEST
1 UNCONFINED COMPRESSION
2 UNCONSOLIDATED-UNDRAINED TRIAXIAL
3 CONSOLIDATED-UNDRAINED TRIAXIAL
U - UNDISTURBED R - REMOLDED

TYPE OF FAILURE
A - BULGE
B - SINGLE SHEAR PLANE
C - MULTIPLE SHEAR PLANE
D - VERTICAL FRACTURE

(a) GRAIN-SIZE DISTRIBUTION CURVE PRESENTED SEPARATELY
(b) STRESS-STRAIN CURVE PRESENTED SEPARATELY

BORING 1, BLOCK 27
SOUTH TIMBALIER AREA

Seafloor at El - 56'

McCLELLAND ENGINEERS

PLATE A-2a

SUMMARY OF TEST RESULTS

SAMPLE NUMBER	PENETRATION FEET	CLASSIFICATION TESTS: LIQUID LIMIT	PLASTIC LIMIT	WATER CONTENT %	UNIT WET WEIGHT LB/CU FT	PERCENT PASSING NO 200 SIEVE	TORVANE: SHEAR STRENGTH KIPS/SQ FT	MINIATURE VANE: TYPE OF TEST	SHEAR STRENGTH KIPS/SQ FT	COMPRESSION TESTS: TYPE OF TEST	WATER CONTENT % Initial	WATER CONTENT % Final	UNIT DRY WEIGHT LB/CU FT	SHEAR STRENGTH KIPS/SQ FT	ϵ_{50} STRAIN %	LATERAL PRESSURE KIPS/SQ FT	FAILURE STRAIN %	TYPE OF FAILURE
							(Continued from Plate A-2a)											
48	126.5	50	22	37			1.32											
49	136.0				106													
51	137.0			42			1.20	U	1.00									
52	146.0				107													
54	147.0			39			1.28	U R	1.56 0.82									
55	155.5	90	28		107					2-U	42		75	1.58		7.1	7.0	A,D
56	156.0				107		1.16											
57	156.5			40				U	1.62									
60	166.5			41			1.30	U	1.40									
61	175.5				110													
62	176.0			34			1.70	U	2.02									
63	185.5				107													
64	186.0						1.60											
65	186.5			39				U	2.54									
67	196.0	87	26		108					2-U	42		76	2.28		5.5	6.1	A
68	196.5			44			1.80	U	2.70									
69	205.5				102													
70	206.0			41			2.30	U	2.46									
71	215.5				109					2-U 2-R	40 39		78 80	2.77 1.84		9.6 9.6	7.9 16.9	A A,C
72	216.0			40			2.10	U	1.96									
74	226.0			46														
75	235.5							U	2.18									
76	236.0	53	25	44			2.60	U	2.71									
78	246.0			47			2.50	U	2.91									
79	255.5				110													
80	256.0				109													
81	256.6			50			2.50	U	2.98									
83	276.0					20a												
85	295.5					4												
86	305.0					5												

LEGEND AND NOTES

TYPE OF TEST
1 - UNCONFINED COMPRESSION
2 - UNCONSOLIDATED-UNDRAINED TRIAXIAL
3 - CONSOLIDATED-UNDRAINED TRIAXIAL
U - UNDISTURBED R - REMOLDED

TYPE OF FAILURE
A - BULGE
B - SINGLE SHEAR PLANE
C - MULTIPLE SHEAR PLANE
D - VERTICAL FRACTURE

(a) GRAIN-SIZE DISTRIBUTION CURVE PRESENTED SEPARATELY
(b) STRESS-STRAIN CURVE PRESENTED SEPARATELY

BORING 1, BLOCK 27
SOUTH TIMBALIER AREA

Seafloor at El - 56'

McCLELLAND ENGINEERS

PLATE A-2b

soil.max

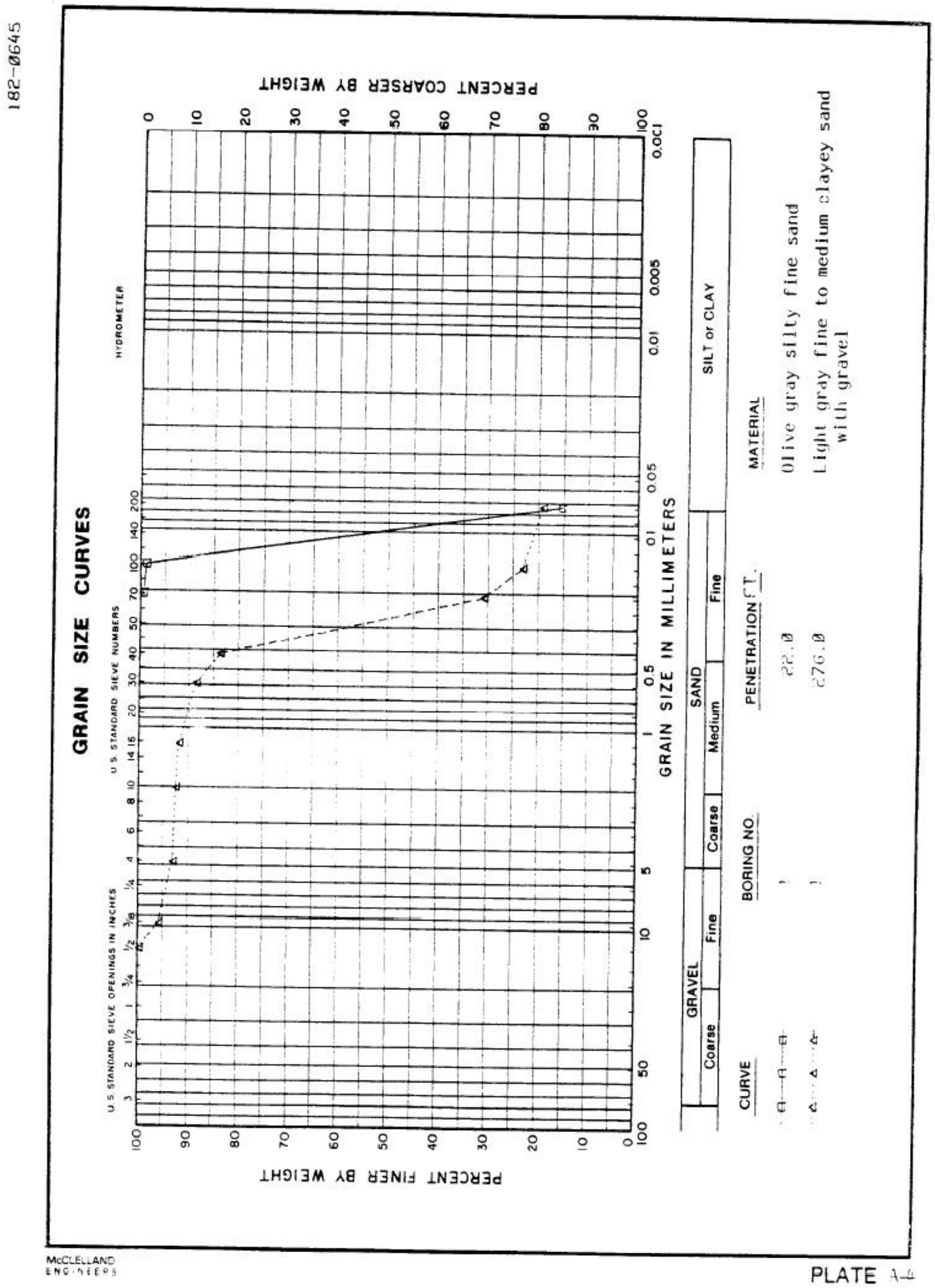
Type of Test	Number of Tests
CLASSIFICATION TESTS	
Plastic and Liquid Limits	8
Sieve analysis through #200 sieve	2
Percent Passing a single sieve (#200)	5
STRENGTH TESTS	
Torvane	27
Miniature Vane	
Undisturbed	25
Remolded	4
Unconsolidated-Undrained	
Triaxial Compression	
Undisturbed	10
Remolded	3
Stress-Strain Curves	6

NUMBER OF FIELD AND LABORATORY TESTS
Boring 1, Block 27
South Timbalier Area

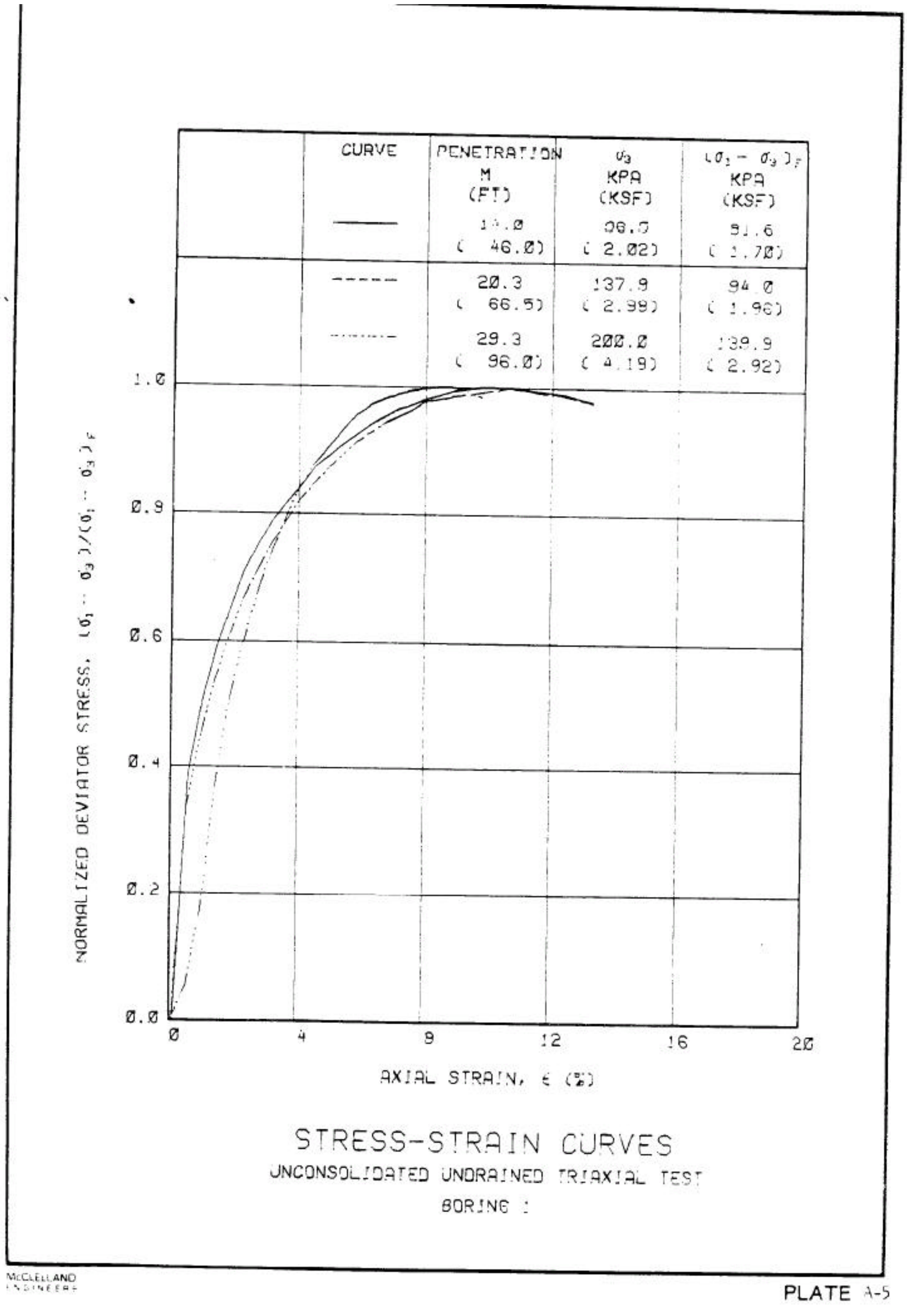
McCLELLAND ENGINEERS

PLATE A-3

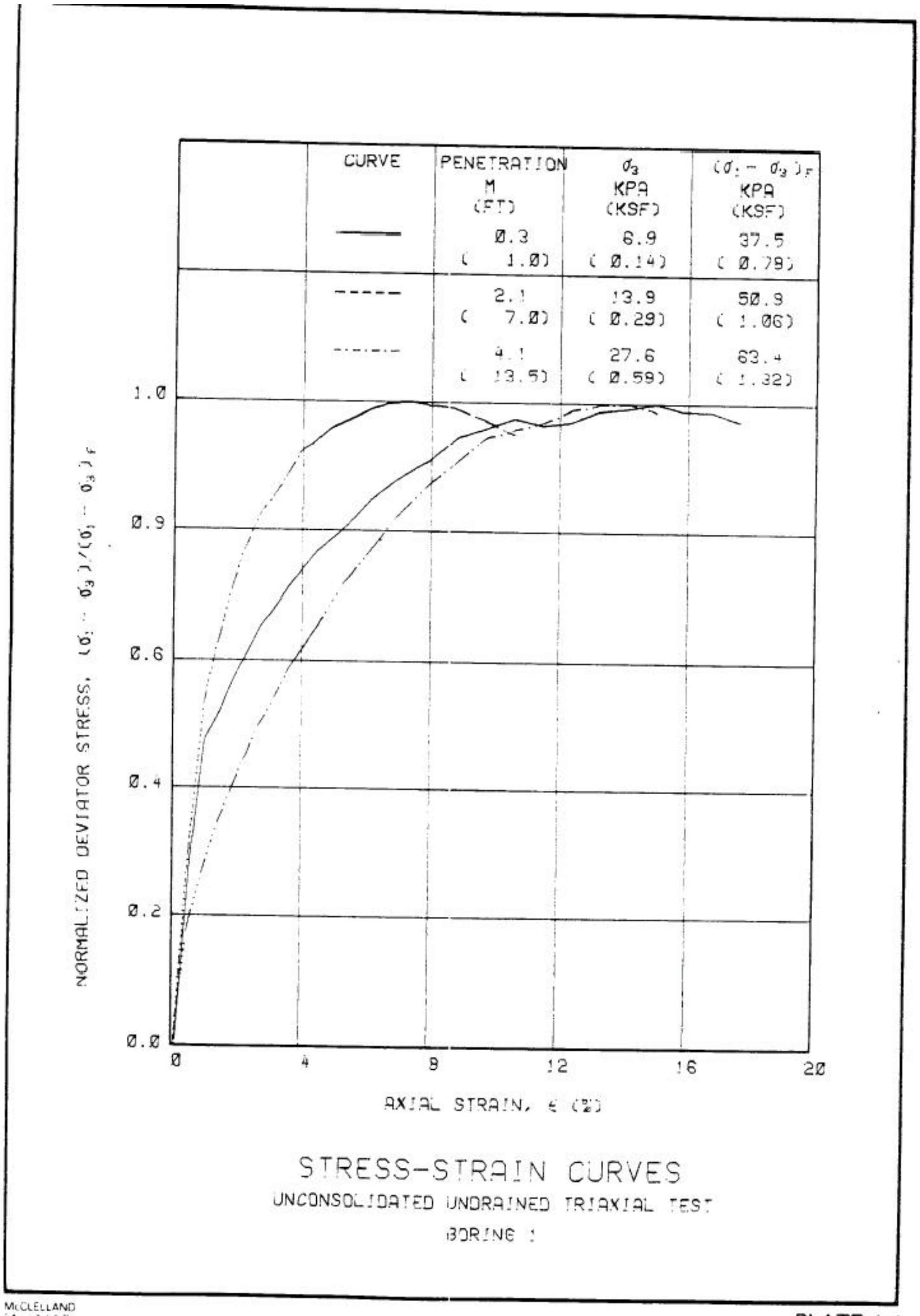
soil.max


182-Ø645
GRAIN SIZE CURVES
PERCENT COARSER BY WEIGHT
PERCENT FINER BY WEIGHT
U.S. STANDARD SIEVE OPENINGS IN INCHES
U.S. STANDARD SIEVE NUMBERS
HYDROMETER
GRAIN SIZE IN MILLIMETERS
GRAVEL
Coarse
Fine
SAND
Coarse
Medium
Fine
SILT or CLAY
CURVE
BORING NO.
PENETRATION FT.
MATERIAL
22.Ø
Olive gray silty fine sand
276.Ø
Light gray fine to medium clayey sand with gravel
McCLELLAND ENGINEERS
PLATE A-4

soil.max


CURVE
PENETRATION M (FT)
KPA (KSF)
KPA (KSF)
(46.0)
(2.02)
20.3
(66.5)
137.9
(2.99)
(1.96)
29.3
(96.0)
200.0
(4.19)
(2.92)
NORMALIZED DEVIATOR STRESS
1.0
0.8
0.6
0.4
0.2
0.0
0
4
8
12
16
20
AXIAL STRAIN, ε (%)
STRESS-STRAIN CURVES
UNCONSOLIDATED UNDRAINED TRIAXIAL TEST
McCLELLAND ENGINEERS
PLATE A-5

soil.max



McCLELLAND ENGINEERS

PLATE A-6

APPENDIX B

AXIAL PILE DESIGN

CONTENTS

AXIAL PILE DESIGN

Method of Analysis

The static method of computing axial pile capacity was used to estimate the ultimate compressive and tensile capacities of pipe piles installed to various penetrations. In this method, the ultimate capacity, Q, for a given penetration is taken as the sum of the skin friction on the pile wall, Q_s, and the end bearing on the pile tip, Q_p, so that:

$$Q = Q_s + Q_p = f A_s + q A_p$$

where A_s and A_p represent, respectively, the embedded surface area and pile end area; f and q represent, respectively, the unit skin friction and unit end bearing. When computing ultimate tensile capacity, the end bearing component in the equation is neglected. Procedures to compute values of f and q are discussed in the following paragraphs.

Unit Skin Friction

Granular Soils. Computation of unit skin friction for pipe piles embedded in granular soils was in general accordance with API RP 2A, Sec. 2.6.4c, and was based on the equation:

$$f = K \bar{\sigma}_v \tan \delta$$

where K = coefficient of lateral earth pressure
$\bar{\sigma}_v$ = effective overburden pressure
δ = angle of friction between soil and pile

Values of K were taken as 0.7 and 0.5 for compressive and tensile loads, respectively. A limiting unit friction was applied to granular soils occurring at significant depths. Values of limiting unit friction were selected from the angle of internal friction of the soil, and were in general agreement with the limiting values presented by McClelland (1974).

Cohesive Soils. For cohesive soils, unit skin friction was computed in accordance with API RP 2A, Sec. 2.27, Para. b.1. In this method, the unit skin friction may be equal to or less than the undrained shear strength of the clay, but may not exceed 1.0 kip per sq ft for shallow penetrations or the undrained shear strength equivalent to a normally consolidated clay for deeper penetrations, whichever is greater.

Unit End Bearing

Granular Soils. Unit end bearing in granular soils was computed using the following equation:

$$q = \bar{\sigma}_v N'_q$$

where $\bar{\sigma}_v$ = effective overburden pressure

N'_q = dimensionless bearing capacity factor that is a function of ϕ, the angle of internal friction of the soil

A limiting value of unit end bearing was applied to granular soils occurring at significant depths. Values of limiting unit end bearing were selected from the angle of internal friction of the soil, and were in general agreement with the limiting values presented by McClelland (1974).

Cohesive Soils. Unit end bearing of piles in clay was computed by the following equation:

$$q = 9\ s_u$$

where s_u = undrained shear strength

For open-end pipe piles in clay and sand, the end bearing was assumed to be limited by the frictional resistance available from the soil plug inside the pile.

REFERENCES

American Petroleum Institute (1982), Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms, API RP 2A, 13th Ed.

ASTM Standards, Part 19 (1982), Natural Building Stones: Soil and Rock, American Society for Testing and Materials.

Matlock, Hudson (1970), "Correlations for Design of Laterally Loaded Piles in Soft Clay," Proceedings, 2nd Offshore Technology Conference, Houston, Vol. 1, pp. 577-594.

McClelland, B. (1974), "Design of Deep Penetration Piles for Ocean Structures," Journal, Geotechnical Engineering Division, ASCE, Vol. 100, July, pp. 709-747.

Reese, L.C., Cox, W.R., and Koop, F.D. (1974), "Analysis of Laterally Loaded Piles in Sand," Proceedings, Sixth Offshore Technology Conference, Houston, Vol. 2, pp. 473-483.

Sullivan, Richard A. and Ehlers, Clarence J. (1972), "Practical Planning for Driving Offshore Pipe Piles," Proceedings, 4th Offshore Technology Conference, Houston, Vol. 1, pp. 805-822.

Annex K

Correction of Charge to Pile Placements during ST21 #97 (Notes from Mr Tommy Broussard, MMS New Orleans Office)

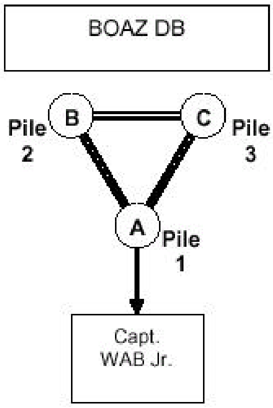
+

– Comparison of In-Situ Measurements from South Timbalier Block 21, Structure #97 with Peak Overpressure / Impulse / Energy Flux Density Results from ARA calculator and Conner Study similitudes equations (Calculations performed by Mr Tommy Broussard, MMS New Orleans Office)

Note on Charge to Pile Placements during ST21 #97 severance (& reshoot).

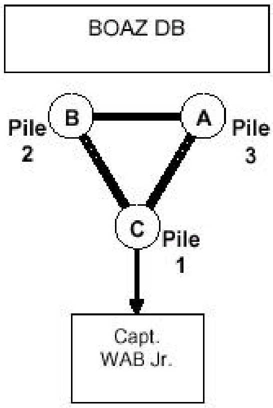
Below is what is currently represented in all of the report tables (*I used Peak Overpressure as an example*).

Peak Overpressure (psi)						
Transducer	Slant Range Pile 1 (ft)	Pile 1 (4.6lb-**A**) Measure	Slant Range Pile 2 (ft)	Pile 2 (50lb-**B**) Measure	Slant Range Pile 3 (ft)	Pile 3 (50lb-**C**) Measure
A	40.3	**139.2**	75.4	**137.9**	75.4	**244.1**
B	46.0	**140.3**	78.7	**167.1**	78.7	**281.6**
C	53.1	**78.8**	83.0	**98.2**	83.0	**279.0**
D	60.6	**86.7**	96.4	**90.9**	96.4	**192.5**
F	69.7	**74.4**	102.4	**134.2**	102.4	**211.6**
G	89.3	**45.5**	125.2	**64.1**	125.2	**151.4**
H	92.1	**93.2**	127.2	**82.7**	127.2	**137.7**
I	95.8	**119.0**	129.9	**118.8**	129.9	**83.3**
L	214.7	**10.1**	249.9	**26.8**	249.9	**41.2**

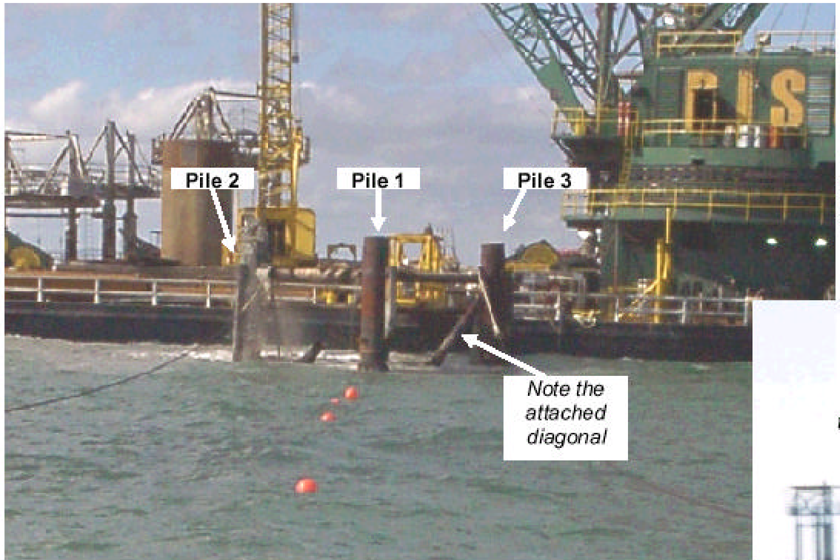


I've noticed for a while that the Charge C measurements were almost twice as high as the same size charge the same distance away, but I thought that it may be due to pile/jacket deterioration. However, when working with my photo's here recently, I notice that pictures of the **Reshoot on Structure 97** (for the failed 4.6lb LSC) indicated that the charge would have been in Pile 3 and not Pile 1 (see next page).

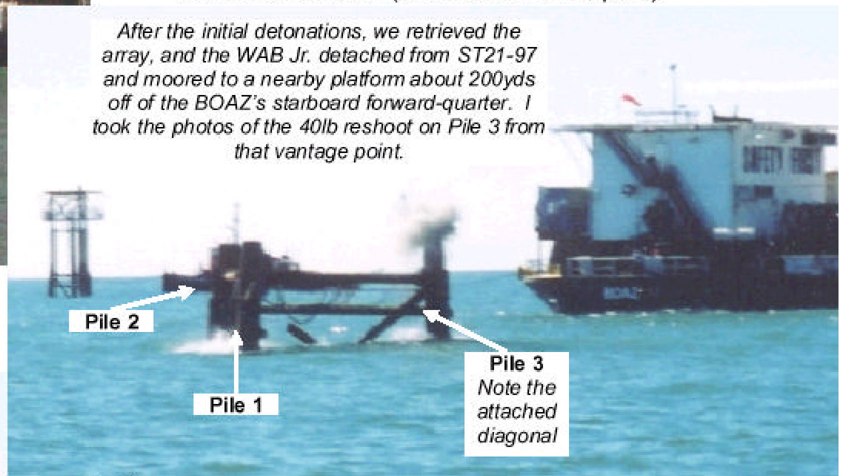
Peak Overpressure (psi)						
Transducer	Slant Range Pile 1 (ft)	Pile 1 (50lb-**C**) Measure	Slant Range Pile 2 (ft)	Pile 2 (50lb-**B**) Measure	Slant Range Pile 3 (ft)	Pile 3 (4.6lb-**A**) Measure
A	40.3	**244.1**	75.4	**137.9**	75.4	**139.2**
B	46.0	**281.6**	78.7	**167.1**	78.7	**140.3**
C	53.1	**279.0**	83.0	**98.2**	83.0	**78.8**
D	60.6	**192.5**	96.4	**90.9**	96.4	**86.7**
F	69.7	**211.6**	102.4	**134.2**	102.4	**74.4**
G	89.3	**151.4**	125.2	**64.1**	125.2	**45.5**
H	92.1	**137.7**	127.2	**82.7**	127.2	**93.2**
I	95.8	**83.3**	129.9	**118.8**	129.9	**119.0**
L	214.7	**41.2**	249.9	**26.8**	249.9	**10.1**



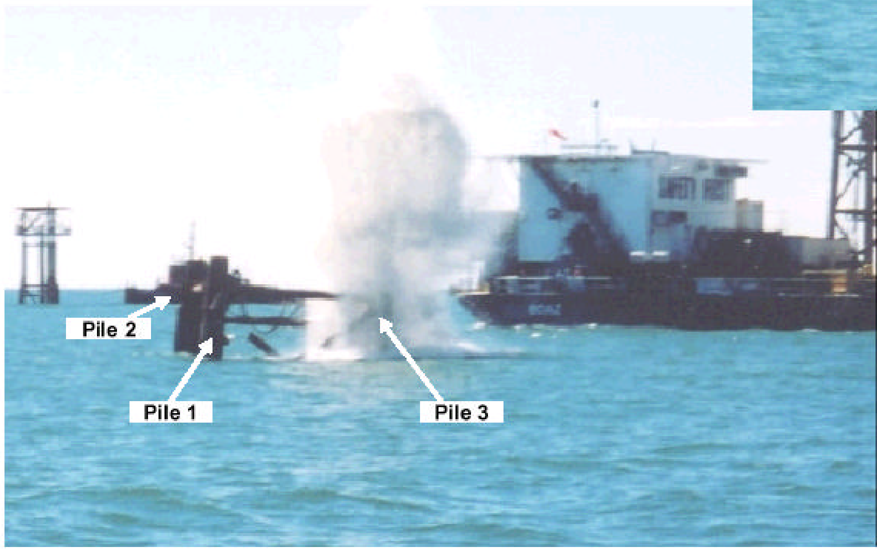
Though I may be a *'day late and dollar short'* for having that section of the Report modified; I at least thought that I would raise it to everyone's attention, and if folks (Janda, Kirklewski, Poe, Leedy) are in agreement, would use this approach for my Conner equation comparisons.



In addition to the **attached diagonal bracing** distinguishing Pile 3 from Pile 1, the initial orientation of the BOAZ had her starboard beam parallel with the horizontal bracing between Piles 2 & 3. When the DB backed off for the detonation(s), she remained in the same orientation (as noted in shot pics).



After the initial detonations, we retrieved the array, and the WAB Jr. detached from ST21-97 and moored to a nearby platform about 200yds off of the BOAZ's starboard forward-quarter. I took the photos of the 40lb reshoot on Pile 3 from that vantage point.



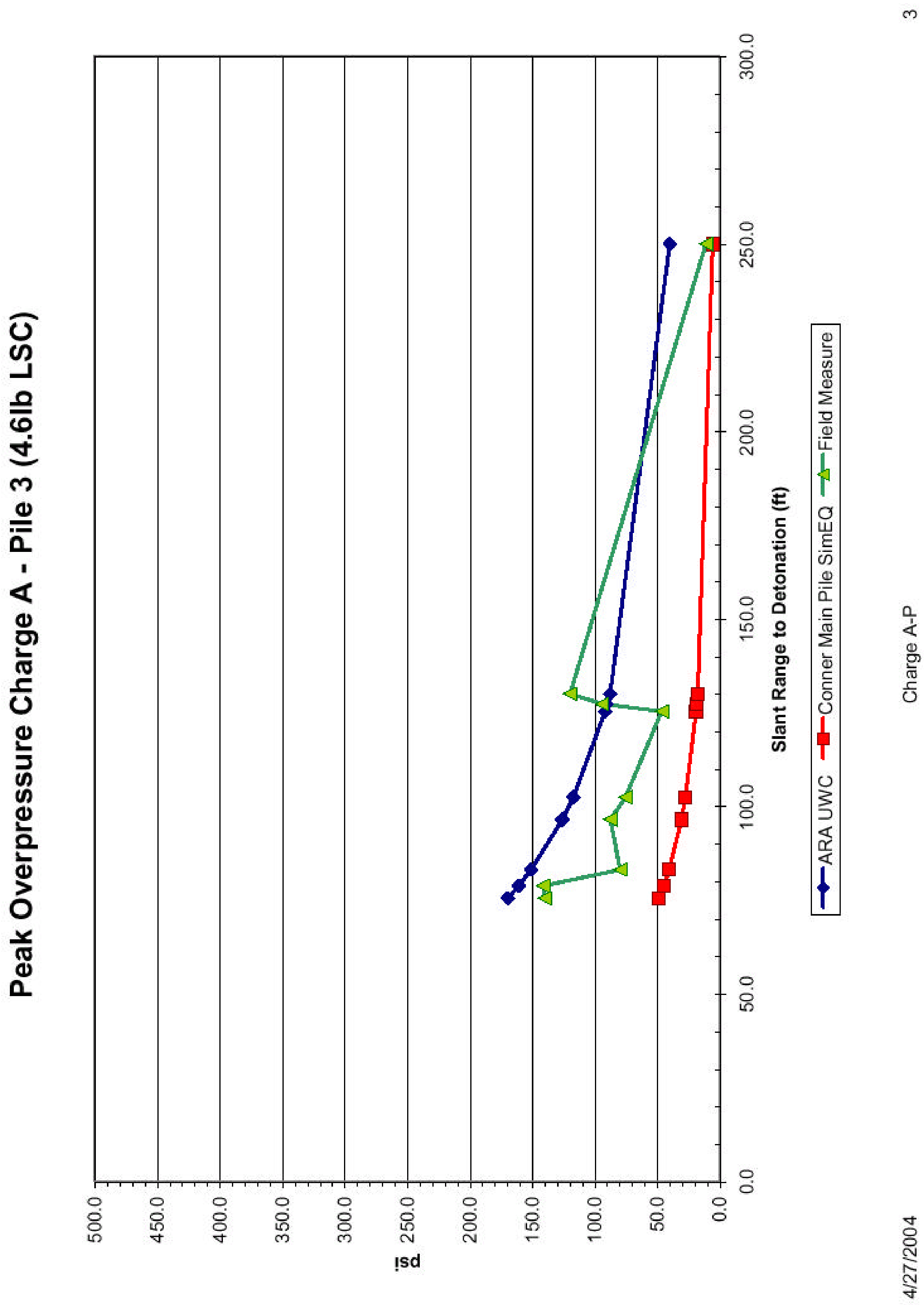
Comparison of In-Situ Measurements from South Timbalier Block 21, Structure #97 with Peak Overpressure / Impulse / Energy Flux Density Results from;

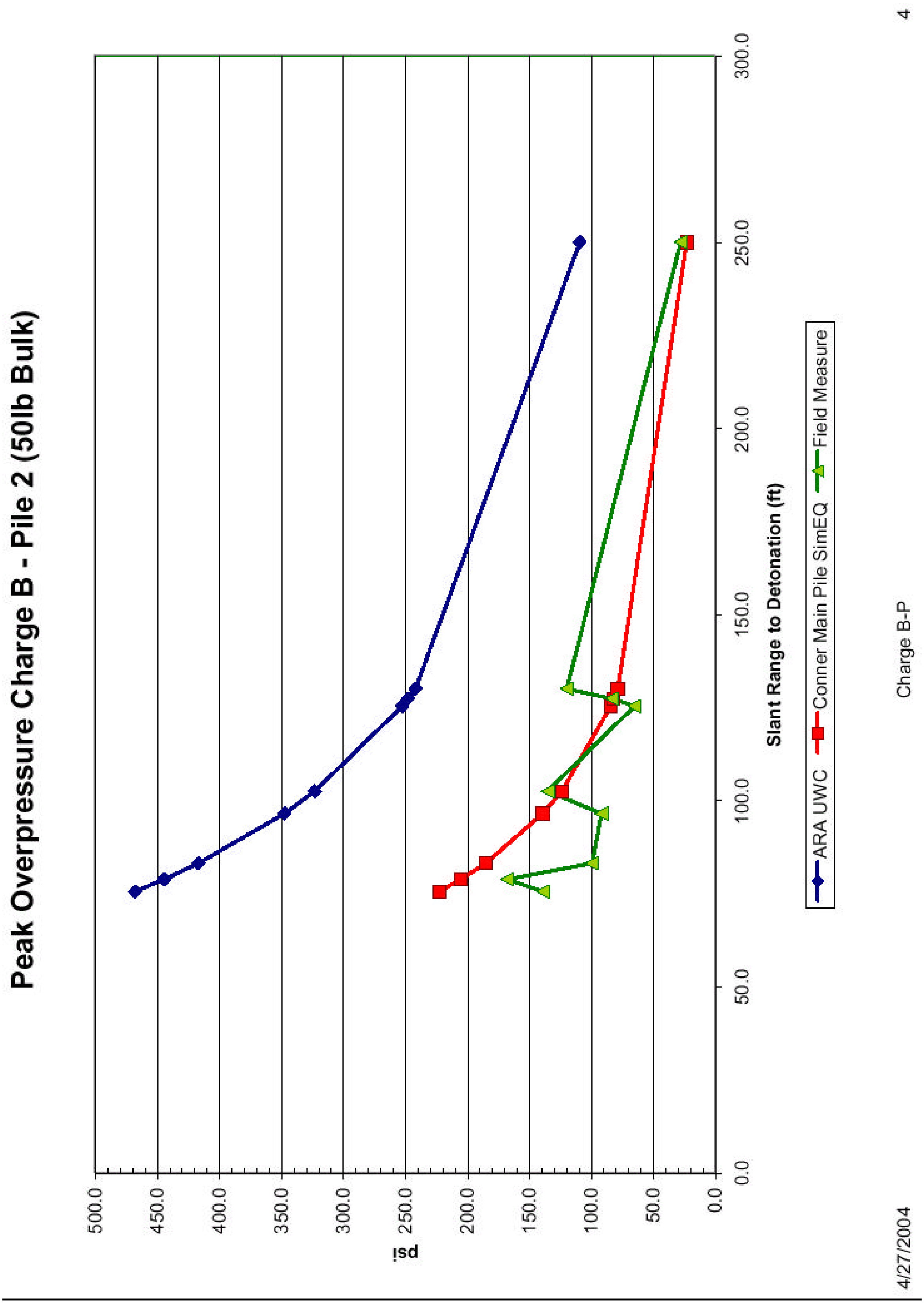
Applied Research Associates' UnderWater Calculator *and*

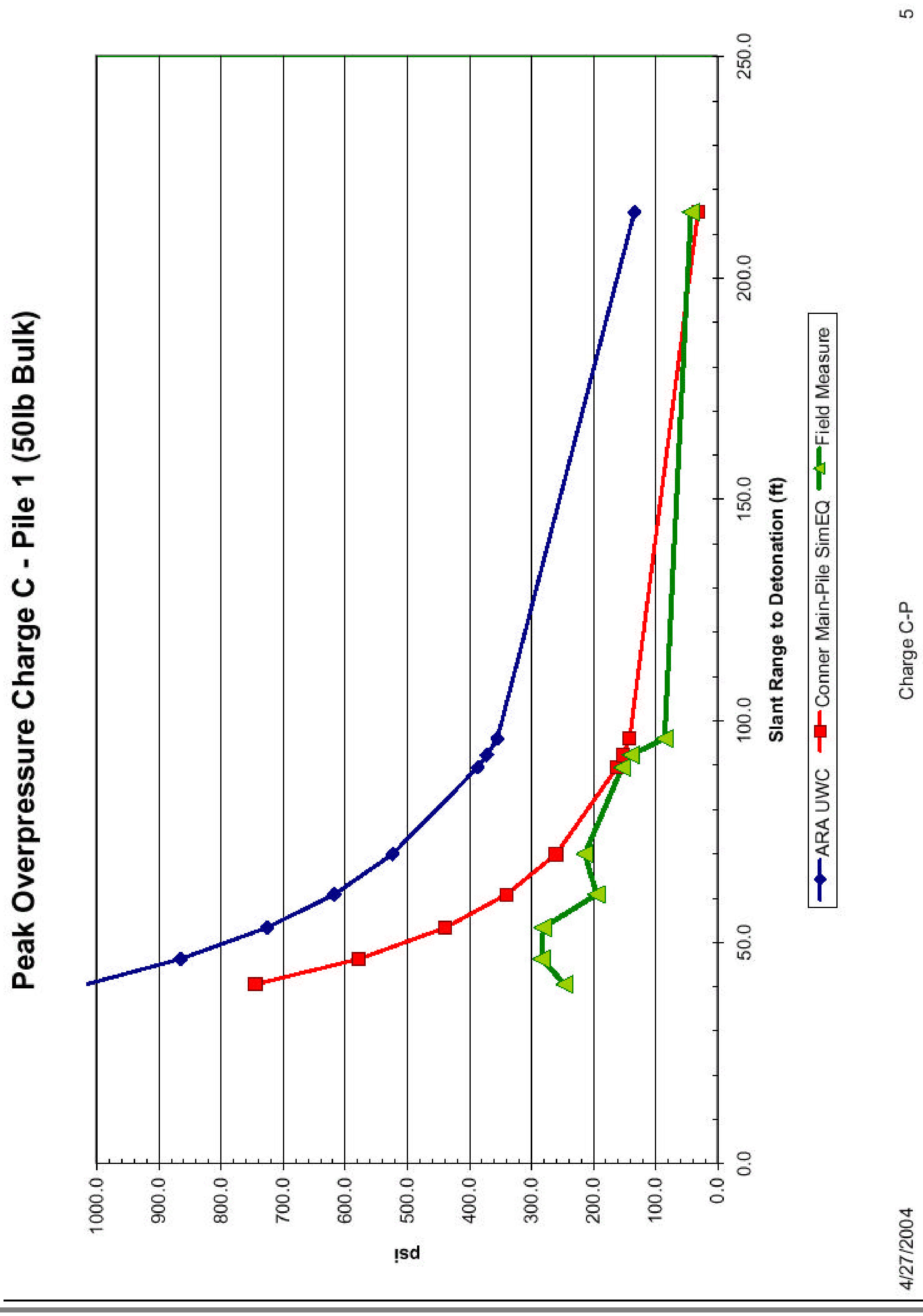
Underwater Blast Effects from Explosive Severance of Offshore Platform Legs and Well Conductors
- NAVSWC TR 90-532 (i.e., the "Conner Study")

Peak Overpressure (psi)

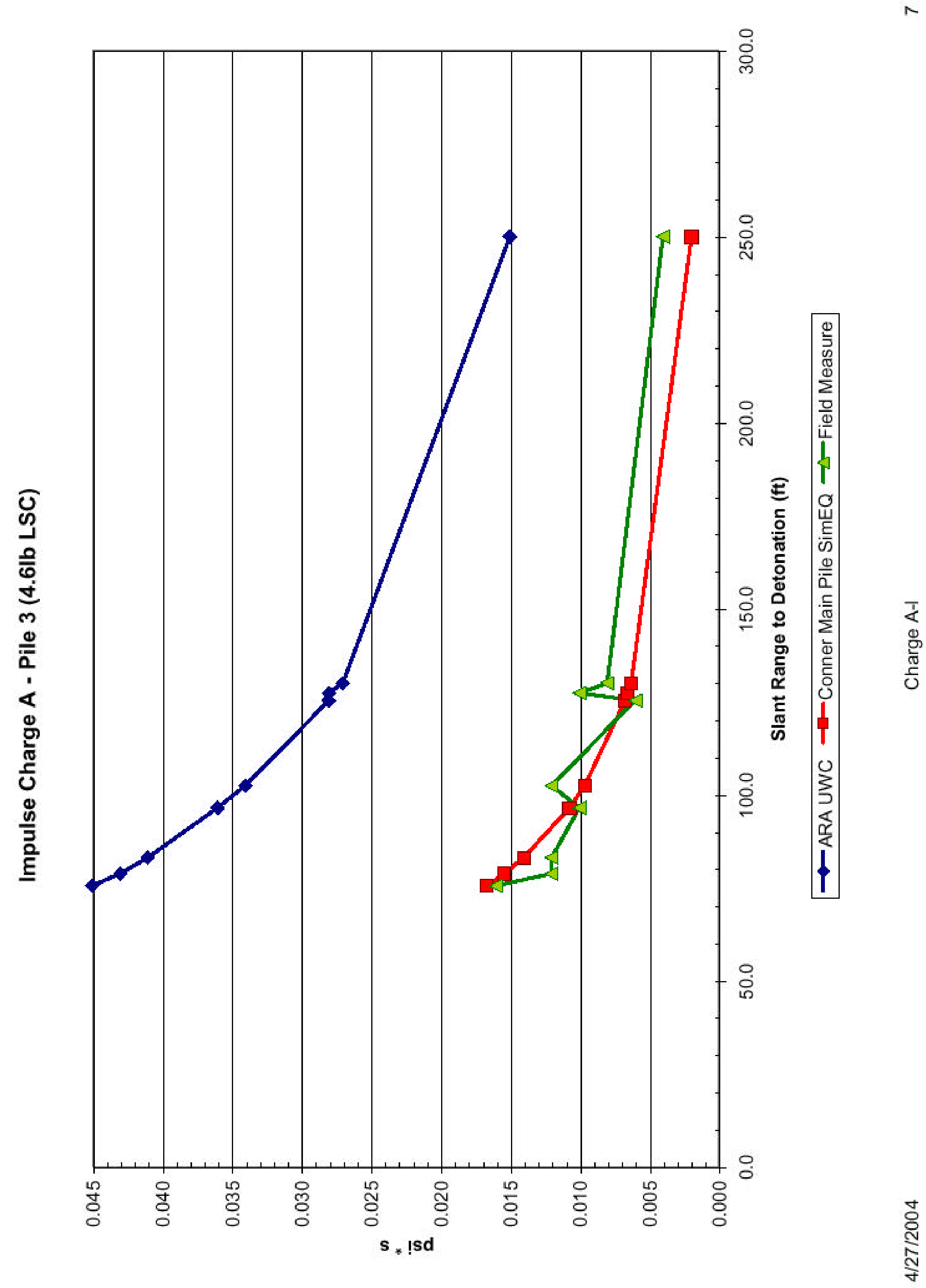
Transducer	Slant Range (ft)	Charge Weight (lb)	ARA UWC	Conner Main Pile SimEQ	Field Measure
Charge A (Pile 3)					
A	75.4	4.6	**168.5**	**47.8**	**139.2**
B	78.7	4.6	**160.0**	**44.0**	**140.3**
C	83.0	4.6	**150.0**	**39.7**	**78.8**
D	96.4	4.6	**124.9**	**29.7**	**86.7**
F	102.4	4.6	**116.2**	**26.5**	**74.4**
G	125.2	4.6	**90.8**	**17.9**	**45.5**
H	127.2	4.6	**89.9**	**17.4**	**93.2**
I	129.9	4.6	**86.9**	**16.7**	**119.0**
L	249.9	4.6	**39.1**	**4.7**	**10.1**
Charge B (Pile 2)					
A	75.4	50.0	**467.2**	**221.6**	**137.9**
B	78.7	50.0	**443.5**	**204.1**	**167.1**
C	83.0	50.0	**415.9**	**184.1**	**98.2**
D	96.4	50.0	**346.3**	**138.0**	**90.9**
F	102.4	50.0	**322.1**	**122.8**	**134.2**
G	125.2	50.0	**251.6**	**83.3**	**64.1**
H	127.2	50.0	**246.8**	**80.8**	**82.7**
I	129.9	50.0	**240.8**	**77.6**	**118.8**
L	249.9	50.0	**108.3**	**21.9**	**26.8**
Charge C (Pile 1)					
A	40.3	50.0	**1014.4**	**742.6**	**244.1**
B	46.0	50.0	**863.0**	**575.3**	**281.6**
C	53.1	50.0	**723.5**	**436.1**	**279.0**
D	60.6	50.0	**615.3**	**337.9**	**192.5**
F	69.7	50.0	**521.1**	**258.0**	**211.6**
G	89.3	50.0	**384.5**	**159.9**	**151.4**
H	92.1	50.0	**369.5**	**150.7**	**137.7**
I	95.8	50.0	**352.6**	**139.6**	**83.3**
L	214.7	50.0	**131.8**	**29.4**	**41.2**

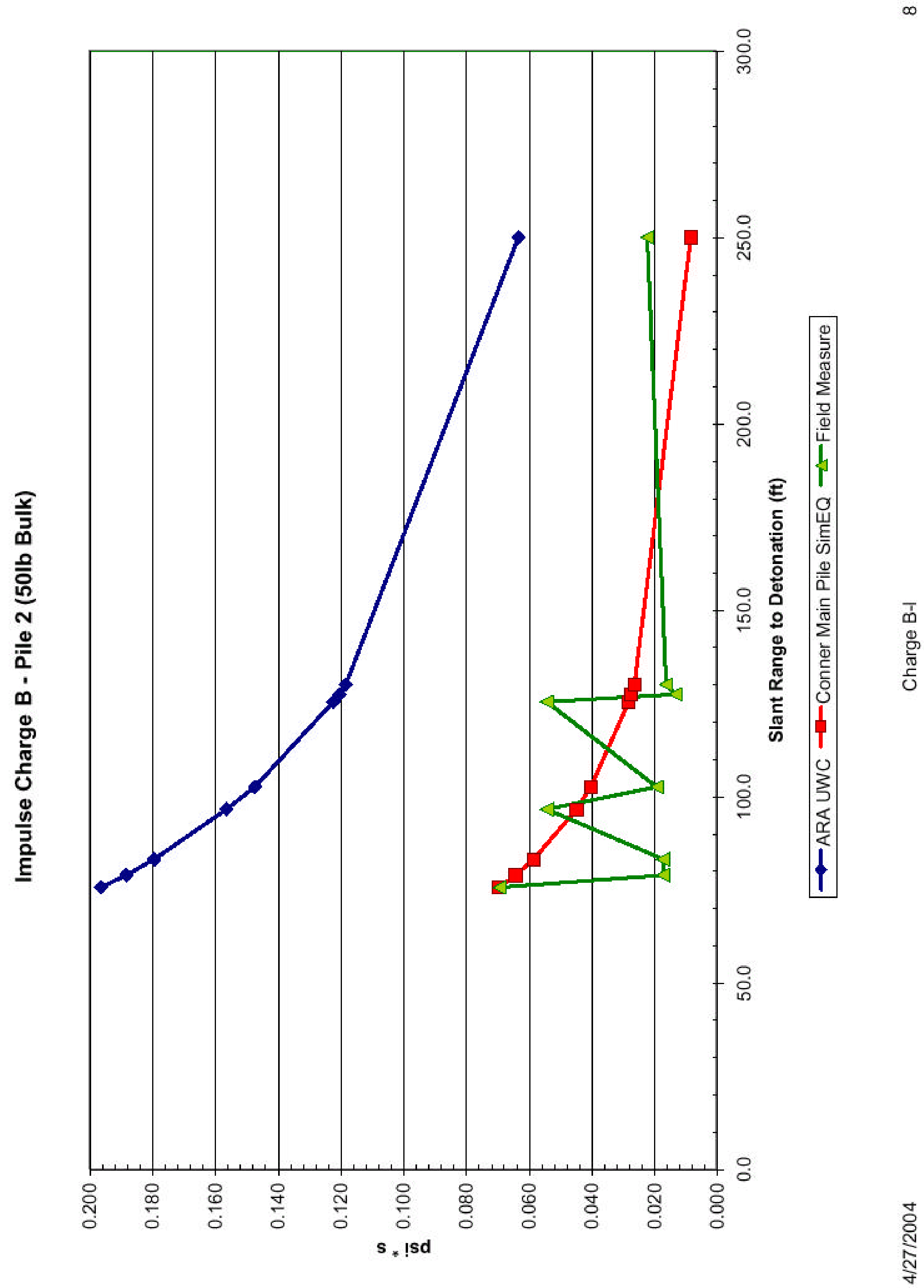

Peak Overpressure Charge A - Pile 3 (4.6lb LSC)
psi
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge A-P
4/27/2004
3

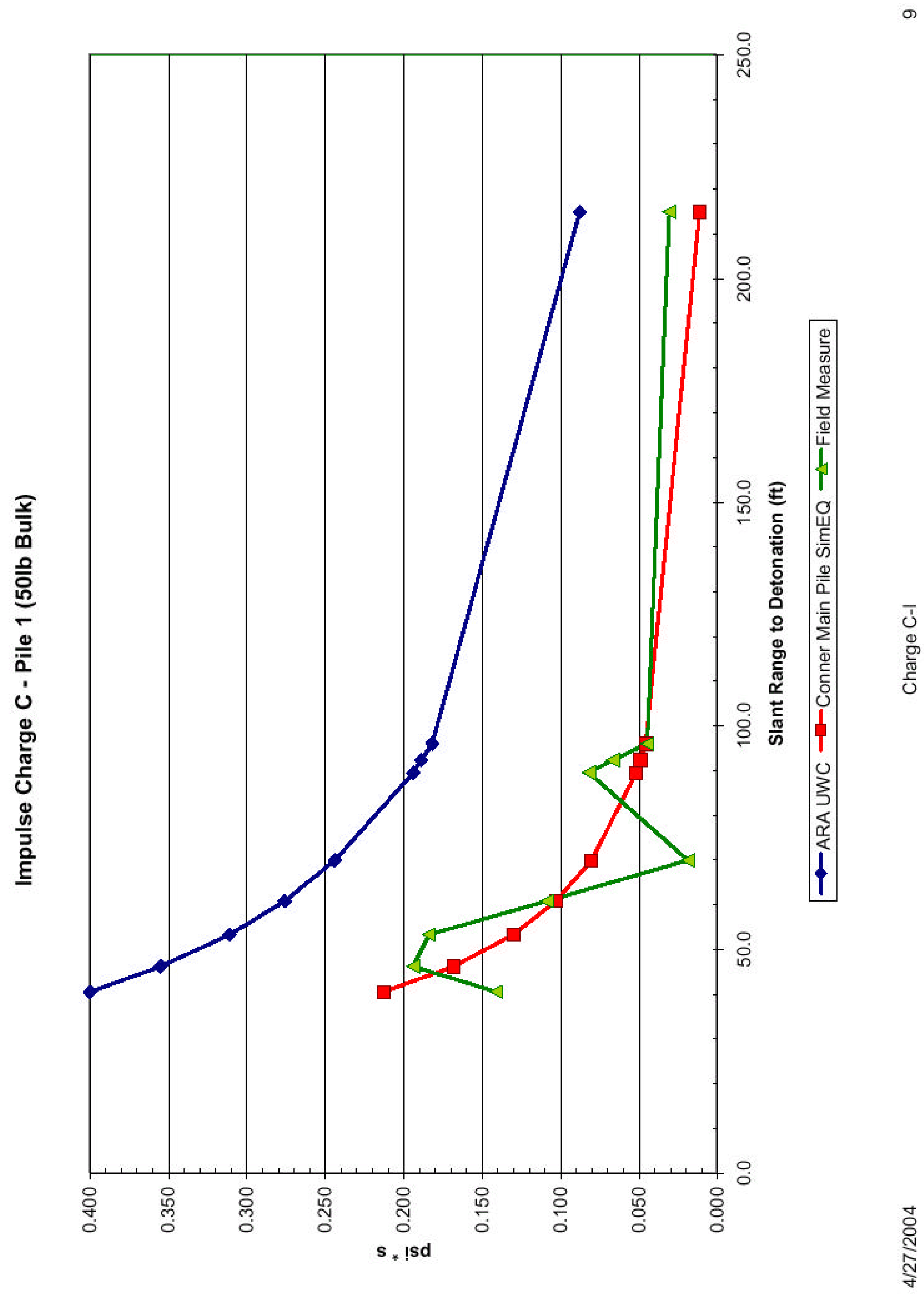

Peak Overpressure Charge B - Pile 2 (50lb Bulk)
psi
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
4/27/2004
Charge B-P
4


Peak Overpressure Charge C - Pile 1 (50lb Bulk)
psi
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0
0.0
50.0
100.0
150.0
200.0
250.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main-Pile SimEQ
Field Measure
Charge C-P
4/27/2004
5

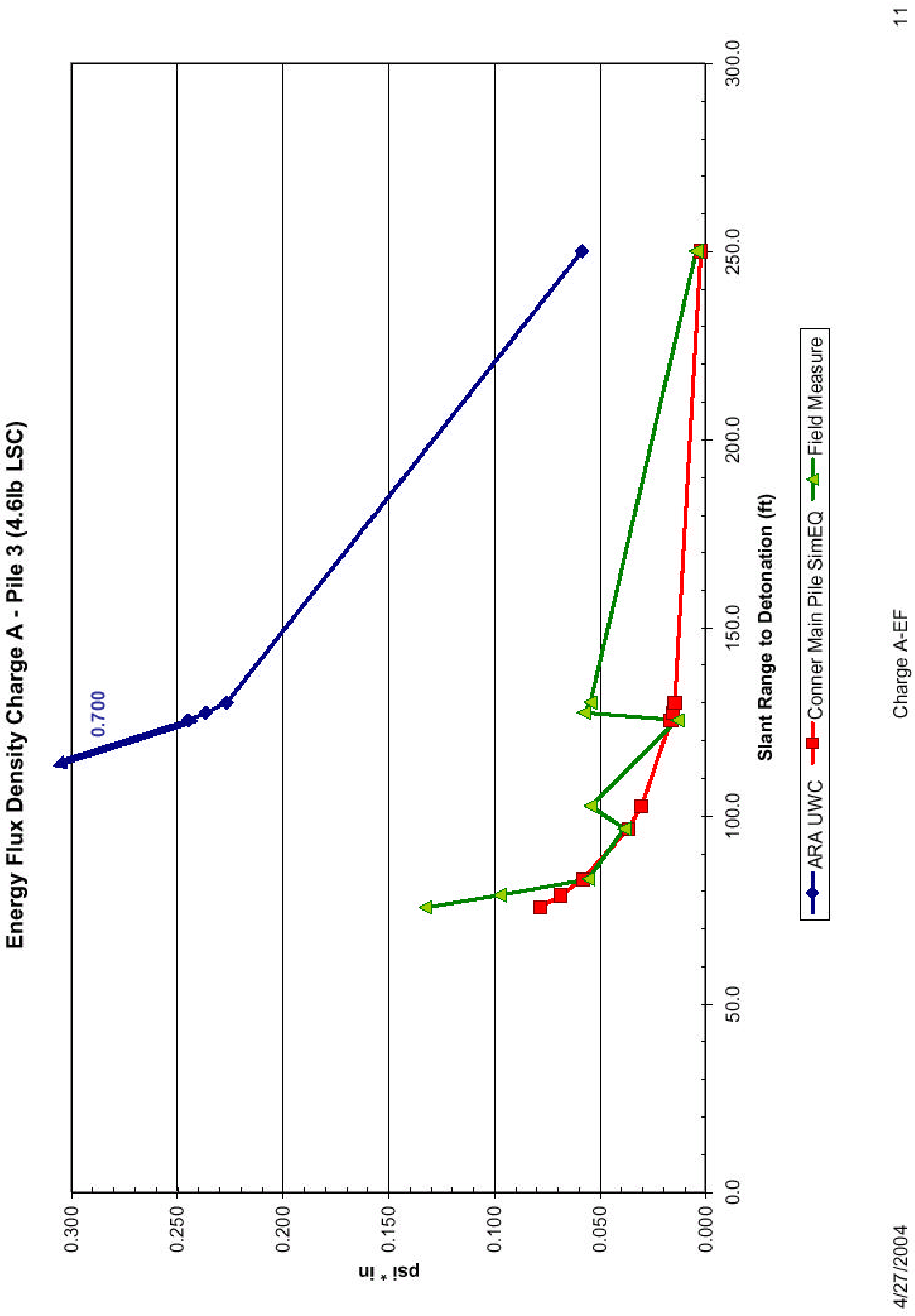
Impulse (psi * s)					
Transducer	Slant Range (ft)	Charge Weight (lb)	ARA UWC	Conner Main Pile SimEQ	Field Measure
Charge A (Pile 3)					
A	75.4	4.6	**0.045**	**0.017**	**0.016**
B	78.7	4.6	**0.043**	**0.015**	**0.012**
C	83.0	4.6	**0.041**	**0.014**	**0.012**
D	96.4	4.6	**0.036**	**0.011**	**0.010**
F	102.4	4.6	**0.034**	**0.010**	**0.012**
G	125.2	4.6	**0.028**	**0.007**	**0.006**
H	127.2	4.6	**0.028**	**0.007**	**0.010**
I	129.9	4.6	**0.027**	**0.006**	**0.008**
L	249.9	4.6	**0.015**	**0.002**	**0.004**
Charge B (Pile 2)					
A	75.4	50.0	**0.196**	**0.069**	**0.069**
B	78.7	50.0	**0.188**	**0.064**	**0.017**
C	83.0	50.0	**0.179**	**0.058**	**0.017**
D	96.4	50.0	**0.156**	**0.044**	**0.054**
F	102.4	50.0	**0.147**	**0.040**	**0.019**
G	125.2	50.0	**0.122**	**0.028**	**0.054**
H	127.2	50.0	**0.120**	**0.027**	**0.013**
I	129.9	50.0	**0.118**	**0.026**	**0.016**
L	249.9	50.0	**0.063**	**0.008**	**0.022**
Charge C (Pile 1)					
A	40.3	50.0	**0.399**	**0.212**	**0.140**
B	46.0	50.0	**0.354**	**0.167**	**0.193**
C	53.1	50.0	**0.310**	**0.129**	**0.183**
D	60.6	50.0	**0.275**	**0.102**	**0.108**
F	69.7	50.0	**0.243**	**0.080**	**0.018**
G	89.3	50.0	**0.193**	**0.051**	**0.081**
H	92.1	50.0	**0.188**	**0.048**	**0.066**
I	95.8	50.0	**0.181**	**0.045**	**0.044**
L	214.7	50.0	**0.087**	**0.011**	**0.030**

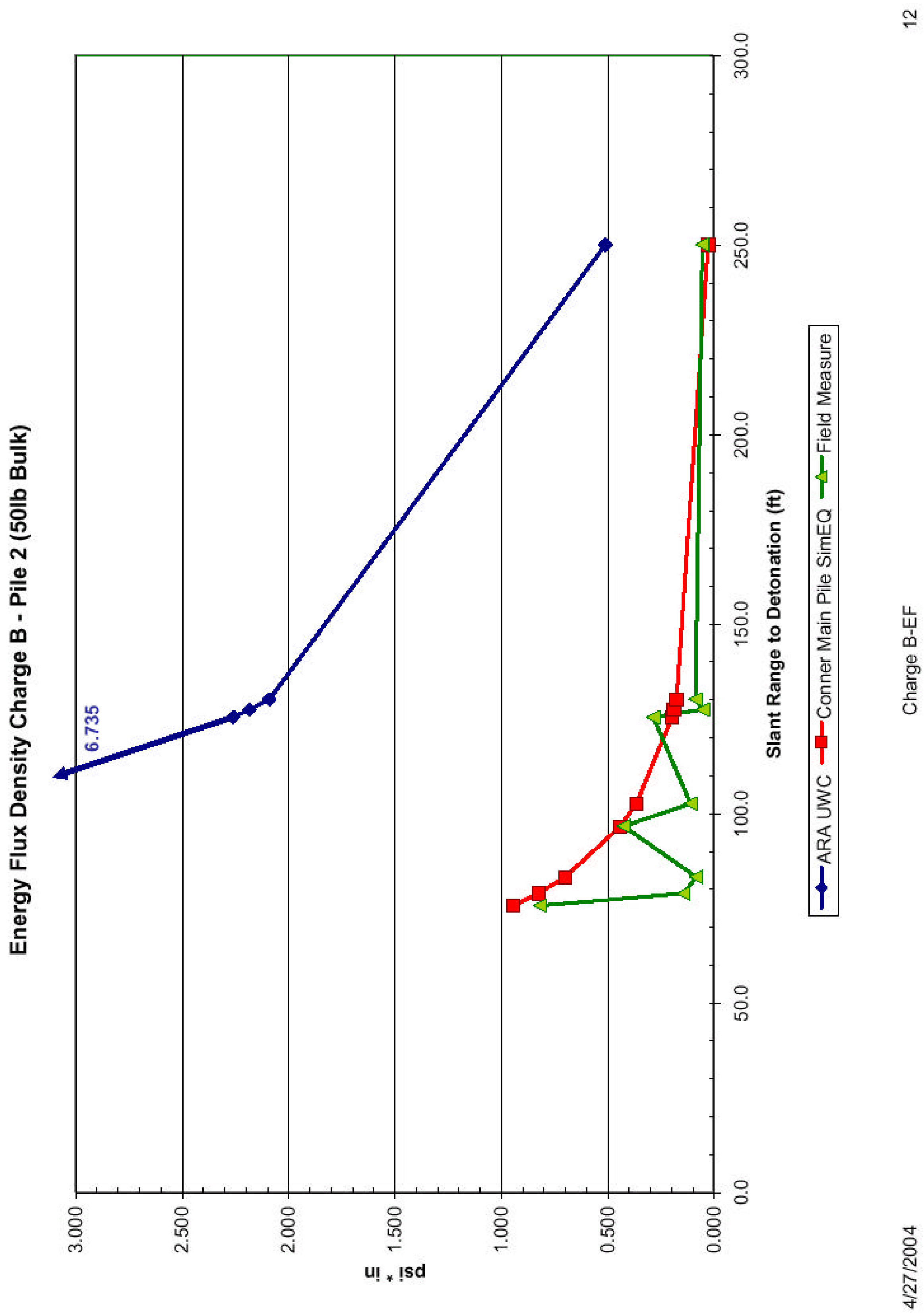

Impulse Charge A - Pile 3 (4.6lb LSC)
psi * s
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge A-I
4/27/2004
7

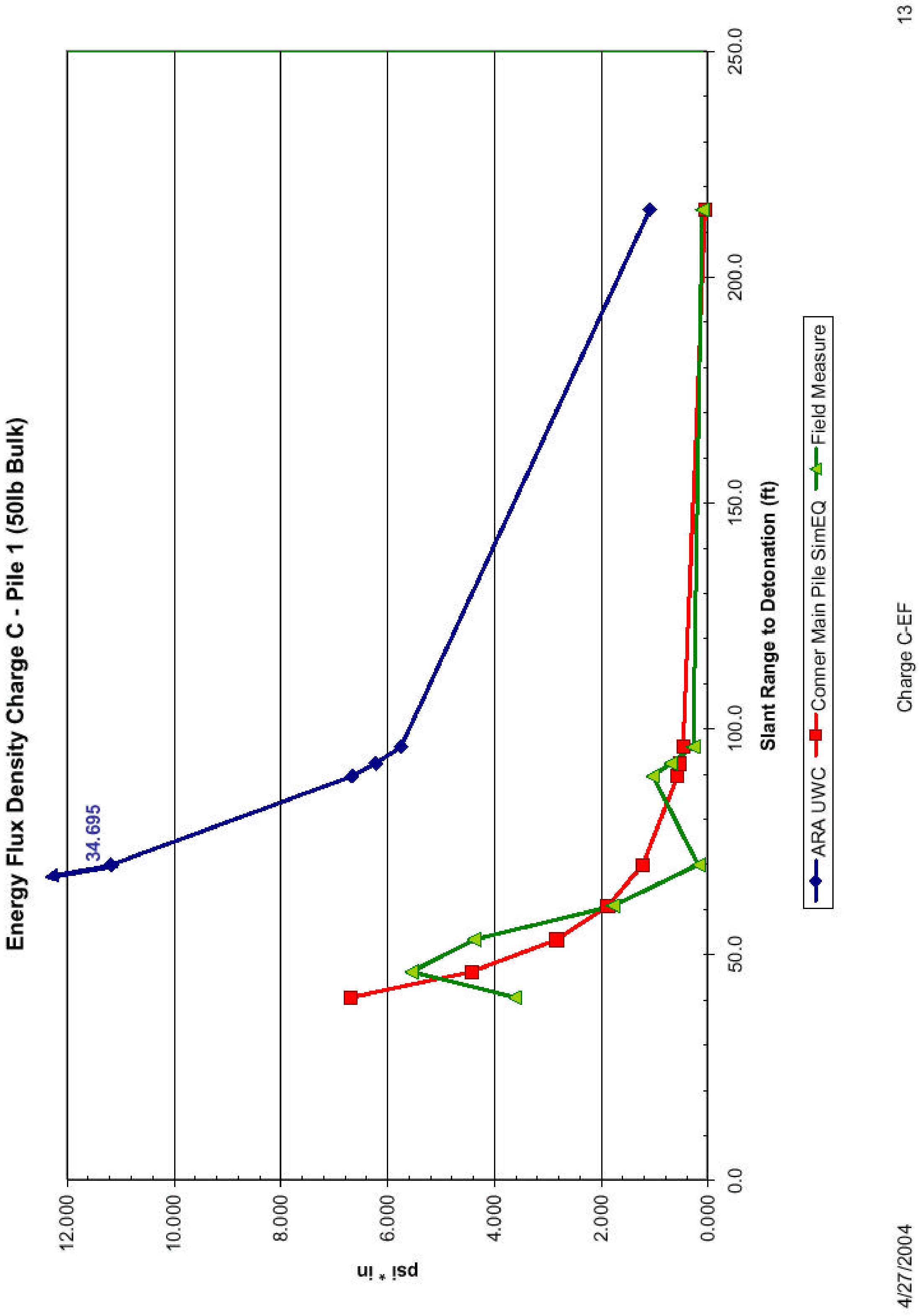

Impulse Charge B - Pile 2 (50lb Bulk)
psi * s
0.200
0.180
0.160
0.140
0.120
0.100
0.080
0.060
0.040
0.020
0.000
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge B-I
8
4/27/2004


Impulse Charge C - Pile 1 (50lb Bulk)
psi * s
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
0.0
50.0
100.0
150.0
200.0
250.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge C-I
4/27/2004
9

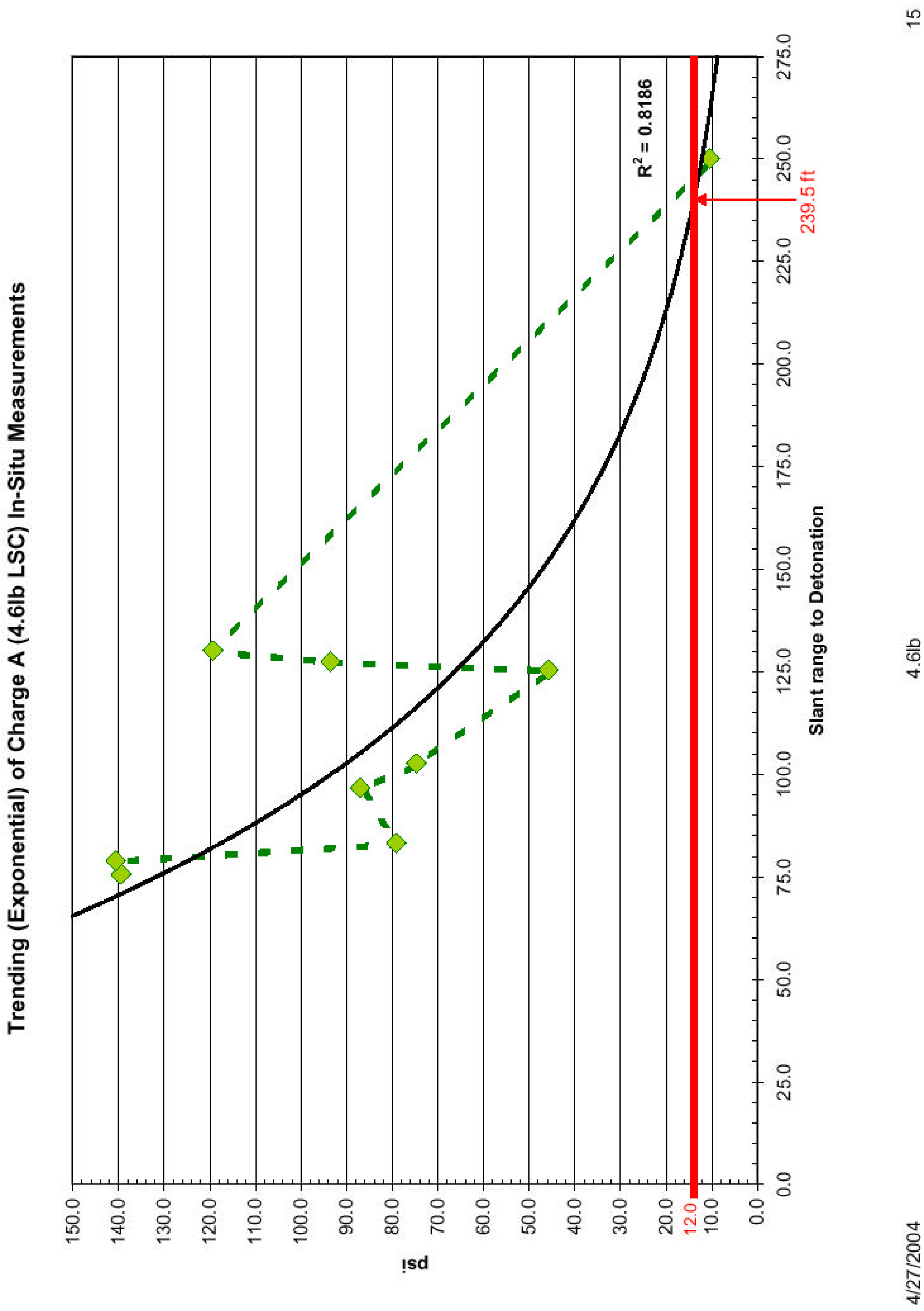
Energy Flux Density (psi * in)					
Transducer	Slant Range (ft)	Charge Weight (lb)	ARA UWC	Conner Main Pile SimEQ	Field Measure
Charge A (Pile 3)					
A	75.4	4.6	**0.700**	**0.078**	**0.132**
B	78.7	4.6	**0.640**	**0.068**	**0.097**
C	83.0	4.6	**0.574**	**0.058**	**0.055**
D	96.4	4.6	**0.420**	**0.036**	**0.038**
F	102.4	4.6	**0.371**	**0.030**	**0.054**
G	125.2	4.6	**0.244**	**0.016**	**0.013**
H	127.2	4.6	**0.236**	**0.015**	**0.057**
I	129.9	4.6	**0.226**	**0.014**	**0.054**
L	249.9	4.6	**0.058**	**0.002**	**0.004**
Charge B (Pile 2)					
A	75.4	50.0	**6.735**	**0.937**	**0.813**
B	78.7	50.0	**6.143**	**0.820**	**0.138**
C	83.0	50.0	**5.482**	**0.694**	**0.078**
D	96.4	50.0	**3.963**	**0.434**	**0.419**
F	102.4	50.0	**3.486**	**0.360**	**0.105**
G	125.2	50.0	**2.252**	**0.192**	**0.280**
H	127.2	50.0	**2.177**	**0.182**	**0.047**
I	129.9	50.0	**2.083**	**0.171**	**0.082**
L	249.9	50.0	**0.506**	**0.022**	**0.051**
Charge C (Pile 1)					
A	40.3	50.0	**34.695**	**6.661**	**3.589**
B	46.0	50.0	**26.337**	**4.403**	**5.526**
C	53.1	50.0	**19.499**	**2.809**	**4.353**
D	60.6	50.0	**14.794**	**1.858**	**1.756**
F	69.7	50.0	**11.144**	**1.199**	**0.162**
G	89.3	50.0	**6.636**	**0.552**	**1.009**
H	92.1	50.0	**6.201**	**0.501**	**0.678**
I	95.8	50.0	**5.725**	**0.443**	**0.259**
L	214.7	50.0	**1.070**	**0.035**	**0.090**

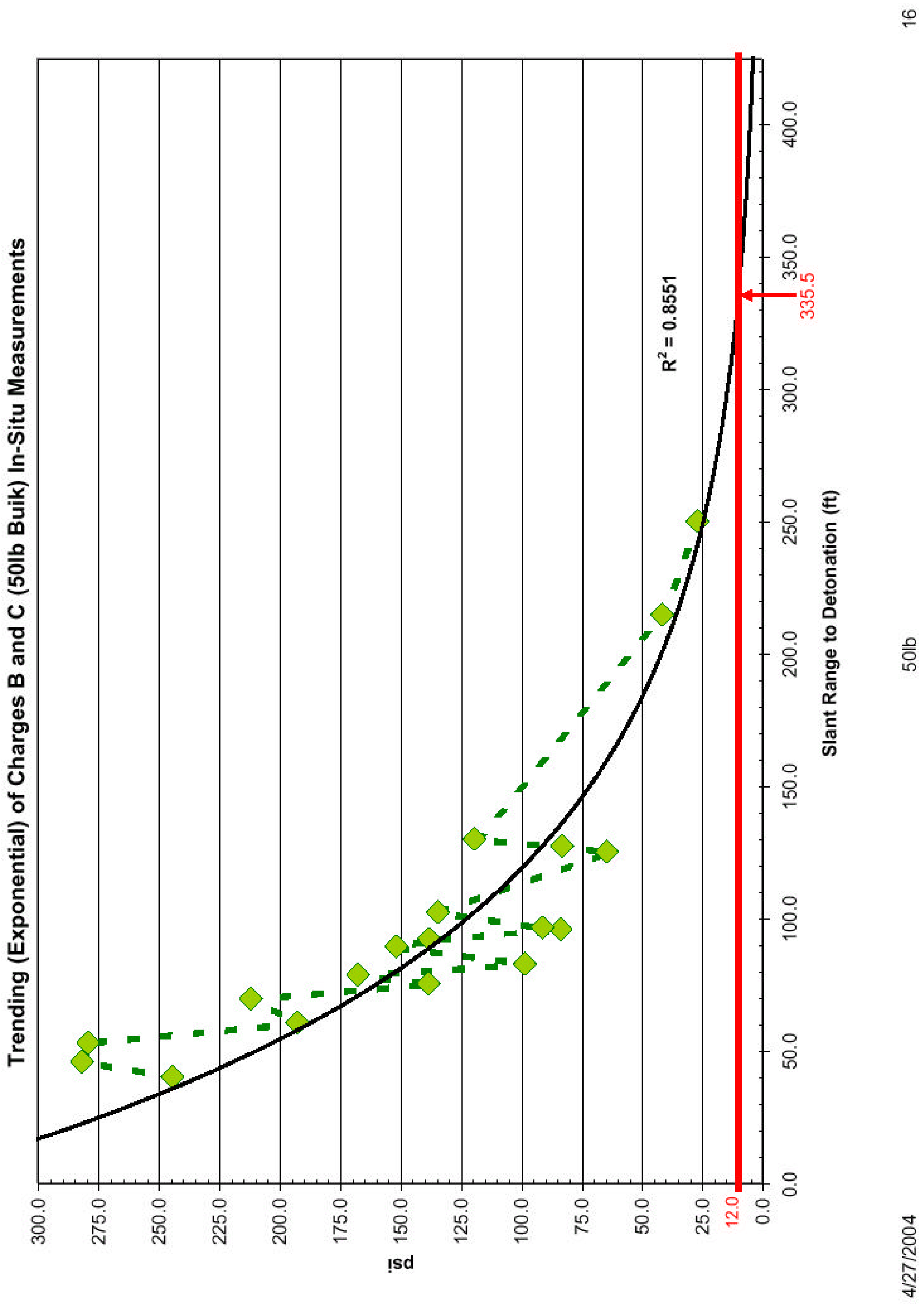

Energy Flux Density Charge A - Pile 3 (4.6lb LSC)
0.700
0.300
0.250
0.200
0.150
0.100
0.050
0.000
psi * in
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge A-EF
11
4/27/2004


Energy Flux Density Charge B - Pile 2 (50lb Bulk)
6.735
psi * in
3.000
2.500
2.000
1.500
1.000
0.500
0.000
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
Charge B-EF
4/27/2004
12


Energy Flux Density Charge C - Pile 1 (50lb Bulk)
34.695
12.000
10.000
8.000
6.000
4.000
2.000
0.000
psi * in
0.0
50.0
100.0
150.0
200.0
250.0
Slant Range to Detonation (ft)
ARA UWC
Conner Main Pile SimEQ
Field Measure
4/27/2004
Charge C-EF
13

Peak Overpressure (psi)		
Transducer	Slant Range (ft)	Field Measure
Charge A (4.6lb LSC)		
A	75.4	**139.2**
B	78.7	**140.3**
C	83.0	**78.8**
D	96.4	**86.7**
F	102.4	**74.4**
G	125.2	**45.5**
H	127.2	**93.2**
I	129.9	**119.0**
L	249.9	**10.1**
Charges B & C (50lb Bulks)		
Aa	40.3	**244.1**
Ba	46.0	**281.6**
Ca	53.1	**279.0**
Da	60.6	**192.5**
Fa	69.7	**211.6**
Ab	75.4	**137.9**
Bb	78.7	**167.1**
Cb	83.0	**98.2**
Ga	89.3	**151.4**
Ha	92.1	**137.7**
Ia	95.8	**83.3**
Db	96.4	**90.9**
Fb	102.4	**134.2**
Gb	125.2	**64.1**
Hb	127.2	**82.7**
Ib	129.9	**118.8**
La	214.7	**41.2**
Lb	249.9	**26.8**


Trending (Exponential) of Charge A (4.6lb LSC) In-Situ Measurements
$R^2 = 0.8186$
239.5 ft
12.0
psi
Slant range to Detonation
15
4.6lb
4/27/2004


Trending (Exponential) of Charges B and C (50lb Buik) In-Situ Measurements
psi
300.0
275.0
250.0
225.0
200.0
175.0
150.0
125.0
100.0
75.0
50.0
25.0
12.0
0.0
Slant Range to Detonation (ft)
0.0
50.0
100.0
150.0
200.0
250.0
300.0
350.0
400.0
335.5
$R^2 = 0.8551$
16
50lb
4/27/2004